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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

August 23, 2006

The contents of this transcript of the proceeding of the United States Nuclear Regulatory Commission Advisory Committee on Reactor Safeguards, taken on August 23, 2006, as reported herein, is a record of the discussions recorded at the meeting held on the above date.

This transcript has not been reviewed, corrected and edited and it may contain inaccuracies.

1 UNITED STATES OF AMERICA

2 NUCLEAR REGULATORY COMMISSION

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4 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

5 SUBCOMMITTEE ON THERMAL HYDRAULICS

6 + + + + +

7 MEETING

8 **OPEN SESSION**

9 + + + + +

10 WEDNESDAY,

11 AUGUST 23, 2006

12 + + + + +

13 ROCKVILLE, MARYLAND

14 + + + + +

15

16 The Committee met at the Nuclear

17 Regulatory Commission, Two White Flint North,

18 Room T2B3, 11545 Rockville Pike, at 8:30 a.m.,

19 Graham B. Wallis, Chairman, presiding.

20

21 COMMITTEE MEMBERS PRESENT:

22 GRAHAM B. WALLIS, Chairman

23 MARIO V. BONACA, Member

24 THOMAS S. KRESS, Member

25 OTTO L. MAYNARD, Member

1 I-N-D-E-X

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

2 (10:14 a.m.)

3 [Meeting in progress.]

4 MR. SMITH: We've done for, you know, our
5 bypass test survivor. It's a specific test. It's not
6 for demo. It is a bypass. Again, we do not do that
7 with the fiber-only. We do it for simulation, a one-
8 pass system where all flow is through a five micron
9 bag filter. So, you know, whatever gets through does
10 not come back around.

11 CHAIRMAN WALLIS: Are you in a position
12 that you can predict how much fiber bypasses the
13 screen in this first wave?

14 MR. SMITH: Yes. Yes. We don't --

15 CHAIRMAN WALLIS: Do you have a theory?

16 MR. SMITH: We do not have a first wave.
17 We have a cumulative effect, because that's what we're
18 worried about.

19 CHAIRMAN WALLIS: And you call it, and
20 then in some way you have --

21 MR. SMITH: We have data that we have
22 correlated together on the size of our strainer. We
23 test each of our clients for fiber, because not all --
24 you know, some clients have mineral rules, some have,
25 you know, Nukon fibers, and there are other -- there

1 are different fibers out there we have tested. To
2 date we have tested mineral and Nukon.
3 CHAIRMAN WALLIS: And so you have a
4 predictive capability. You can say if you have a
5 certain area of screen and certain hole size, then
6 you --
7 MR. SMITH: For our strainer, we are
8 predicting this is the quantity of material and this
9 is the characteristic. So in that --
10 CHAIRMAN WALLIS: About how much of it
11 gets through?
12 MR. SMITH: We are down into small cubic
13 feet, you know, one cubic foot of glass.
14 CHAIRMAN WALLIS: For all the strainers or
15 per strainer?
16 MR. SMITH: Oh, this is for the complete -
17 -
18 CHAIRMAN WALLIS: Complete assembly in the
19 plant?
20 MR. SMITH: Yes. And I'll show you -- we
21 have another feature. We have a feature we have added
22 to our strainer, and we do a second. But I'll keep
23 going, and I'll --
24 This is just a little filter picture here
25 showing the beginning of our test. We introduced the

1 fiber in very small batches to allow it to accumulate
2 on the strainer module. In this we understand that as
3 you add little batches and little batches and little
4 batches that gives it opportunity to pass through.
5 And, again, in the real world you don't
6 know if all the fiber is going to hit it in one big
7 slug, or you're going to hit it in little trickle
8 streams. So we introduce it in the trickle stream
9 fashion, giving it the most opportunity to get
10 through.
11 This is a half-inch loading on it. You'll
12 see some non-uniform loading going on. There's still
13 clean surface area there, and we keep --
14 CHAIRMAN WALLIS: It looks as if it's all
15 on the outside of the cylinder.
16 MR. SMITH: It has gone down the center as
17 well.
18 MR. ZIGLER: If you would look in here,
19 you would see portions of it. But the inside of the
20 cylinder would normally be the last one to do it,
21 because it has a tangential velocity vector on into
22 the surface of it. So it -- actually, in the inside
23 we see a lot of what we like to almost call it -- it's
24 a self-cleaning phenomena, and it's the only -- when
25 your inside gets filled in, but you finally clear this

1 last remaining area, which is the inside of it.

2 CHAIRMAN WALLIS: I don't understand the

3 design of your strainer. You have this can, and you

4 have something inside it, some kind of --

5 MR. SMITH: Yes, let me -- I've got a

6 slide here.

7 CHAIRMAN WALLIS: -- shape. And fibers

8 can actually go inside the cylinder?

9 MR. SMITH: Yes. It's --

10 CHAIRMAN WALLIS: They could fill the

11 whole cylinder, and they do.

12 MR. SMITH: They're concentric.

13 CHAIRMAN WALLIS: But if you fill the

14 cylinder, then it doesn't seem to really matter. They

15 can't get into it, so it doesn't matter --

16 MR. SMITH: That's right.

17 CHAIRMAN WALLIS: -- how much area you

18 have inside. It just becomes limited presumably by

19 the outside.

20 MR. SMITH: Outside and down through the

21 center.

22 CHAIRMAN WALLIS: And when you showed us

23 these things completely buried in debris, presumably

24 the inside is full of debris and there's very little

25 flow that goes through there. So having all that area

1 doesn't help you, then.

2 MR. SMITH: It accumulates the debris.

3 MR. ZIGLER: But, again, just remember

4 that we are talking about a very, very highly porous

5 bed, because the beds are uncompressed.

6 CHAIRMAN WALLIS: But the effective area

7 of the screen is very different when it becomes

8 clogged.

9 MR. ZIGLER: Oh, absolutely. That's the

10 reason for that jump that you saw in the data.

11 Absolutely.

12 MR. SMITH: Yes.

13 CHAIRMAN WALLIS: As long as you just have

14 a little bit of fibers and all that area is useful --

15 MR. ZIGLER: Right.

16 CHAIRMAN WALLIS: -- plug up the hole

17 inside --

18 MR. SMITH: Dr. Wallis, we designed the

19 strainer with gaps and spacing between these to

20 accommodate the debris.

21 CHAIRMAN WALLIS: When you say 3,000

22 square feet of strainer, that's all these wiggles and

23 squiggles inside.

24 MR. ZIGLER: Absolutely.

25 CHAIRMAN WALLIS: I mean, if you just look

1 at the outside of the cans, it's much less.

2 MR. SMITH: Oh, yes. Yes.

3 CHAIRMAN WALLIS: But that's what you're

4 really faced with when you have a heavy load. It's

5 the outside of --

6 MR. SMITH: And we base the thickness, the

7 predicted debris load thickness on the surface area,

8 so that we're not just jamming it all in.

9 CHAIRMAN WALLIS: Base it on all the -- on

10 the superficial surface area of the cylinder, or the

11 area of all the inside?

12 MR. SMITH: The inside --

13 CHAIRMAN WALLIS: So you have a .002

14 approach velocity based on all of the area --

15 MR. SMITH: Right.

16 CHAIRMAN WALLIS: -- and maybe a .001

17 velocity based on the cylinders themselves or

18 something?

19 MR. SMITH: Exactly, yes. But as -- like

20 I say, we have sized the strainers, the gap, the

21 spacing between the gaps to accommodate the predicted

22 quantity of debris that's arriving.

23 MEMBER MAYNARD: More debris loading the

24 more debris you have in there, isn't it? The more

25 modules of strainers that you put on --

1 MR. SMITH: Exactly. Exactly.

2 MEMBER MAYNARD: So it's not limited to

3 just one --

4 MR. SMITH: Well, going on with our fiber

5 bypass testing, again, most of the fiber bypass occurs

6 when the -- again, as I stated before on the first --

7 the positing on the strainer. Fiber bypass

8 essentially becomes zero once that bed completely

9 forms. We have observed the bypass is proportional to

10 the strainer area and the approach velocity.

11 The quantity of bypass, you know, can be

12 significant. This is some bypass material we've got -

13 - we've collected, just to show some of the material

14 that has gone downstream of the perforated plate of

15 our strainer.

16 CHAIRMAN WALLIS: And got caught on

17 another strainer.

18 MR. SMITH: It's collected in a five

19 micron bag, a bag filter, we have a bag filter section

20 downstream. So it is collected, dried, weighed, and

21 characterized.

22 MR. ZIGLER: And, in fact, the filter is

23 very, very highly effective, that we have had to

24 change the procedure of doing the bypass testing by

25 first putting in a five micron bag and letting the

1 water circulate for a considerable amount of time to
2 clean the water first and then we will put in the bag
3 that we were using for the test.
4 CHAIRMAN WALLIS: Now, when you say
5 "quantitative fiber bypass is significant" --
6 MR. SMITH: It can be significant in
7 that --
8 CHAIRMAN WALLIS: -- what does that mean?
9 MR. SMITH: We're talking here -- we've
10 seen a good amount of quantity from standard
11 perforated plate on bypass, and I wanted to go on, we
12 add a separate --
13 CHAIRMAN WALLIS: Well, you say
14 "significant," but then you were telling me before
15 that only one or two cubic feet got through in the --
16 MR. SMITH: That's with our secondary
17 feature.
18 CHAIRMAN WALLIS: Oh, with your secondary
19 feature.
20 MR. SMITH: Yes.
21 CHAIRMAN WALLIS: Oh, okay.
22 MR. SMITH: The next slide --
23 CHAIRMAN WALLIS: Well, when you say
24 "significant," that means five percent gets through or
25 something, when -- it doesn't tell me what you mean by

1 "significant."

2 MR. SMITH: I have some data I can provide

3 you with.

4 CHAIRMAN WALLIS: Does one truckload get

5 through or --

6 MR. SMITH: I provided the staff some

7 information on what we had the other day, so -- it's

8 not truckload, but it is a percentage, many cubic

9 feet.

10 CHAIRMAN WALLIS: Many cubic feet.

11 MR. SMITH: Yes, I could say that.

12 CHAIRMAN WALLIS: That's enough to make a

13 difference in the lower plenum of the reactor flume.

14 MR. SMITH: Yes, potentially. I don't

15 know -- I don't know the blockage issue of that -- the

16 fuel itself. We had a secondary feature.

17 MEMBER KRESS: The previous slide showing

18 -- it looks a little strange to me. It's like the

19 fiber had built up a layer and then broke off in

20 chunks.

21 MR. SMITH: Yes. This is in our bag.

22 CHAIRMAN WALLIS: This is in the bag.

23 MR. SMITH: If you dump the bag out. It

24 is --

25 MEMBER KRESS: That happened in the bag,

1 you think?

2 MR. ZIGLER: Oh, yes, it clumps up. It

3 looks like puff balls --

4 MR. SMITH: Yes.

5 MR. ZIGLER: -- of fiber.

6 CHAIRMAN WALLIS: And it felts,

7 presumably. Isn't it felt a little bit? It's --

8 MR. SMITH: Excuse me?

9 CHAIRMAN WALLIS: It felts. It's like

10 felt. It --

11 MR. SMITH: Yes.

12 CHAIRMAN WALLIS: The fibers attach --

13 MR. ZIGLER: It's because of the long

14 strands of fiber. I mean, the strands are pretty

15 large.

16 MR. SMITH: It actually collects in our

17 bag downstream, and this is after we dried it, dump it

18 out, take some photos of it, we've got some

19 characterization on it. We've added our -- we have a

20 secondary feature we add that collects or entraps the

21 fiber after it gets through the holes within our

22 perforated plate.

23 This is basically a -- just a secondary

24 stainless steel knitted wire mesh material, it's very

25 porous, slide up inside of it. And, again, we've got

1 an inner and an outer tube here, so it's a cylinder
2 that goes inside. So all the fiber -- or the flow
3 passes through and then comes out this little wire
4 mesh secondary filter.
5 CHAIRMAN WALLIS: Looks like a way to
6 create high head loss.
7 MR. SMITH: We test all of our strainers
8 with this material in place. Okay? So it does add
9 some head loss, but it's not extremely high. But you
10 do pay a little bit on your head loss, but it does a
11 very nice job of collecting bypass of fiber. So we've
12 used that, and that then has gotten it down to that
13 less than a cubic foot or so. And this --
14 CHAIRMAN WALLIS: One wonders if you
15 really need it to be so thick. I mean --
16 MR. SMITH: We have --
17 CHAIRMAN WALLIS: Do the fibers actually
18 penetrate much into this porous media?
19 MR. SMITH: It's pretty -- a loose, loose-
20 knit wire --
21 CHAIRMAN WALLIS: Most of them are on the
22 surface.
23 MR. SMITH: Yes, they go down there just
24 a little ways.
25 MR. ZIGLER: What happened, Dr. Wallis --

1 and we have modeled this with the CFD and we can
2 actually see it -- and the sense of what happens is
3 that your flow stream now becomes basically slightly
4 turbulent inside, and your flow stream in the hole,
5 which before you had the hole, your fiber would have
6 punched right through and then down on it.
7 Now you have the surface right behind the
8 hole on it, so that flow stream is not perpendicular
9 anymore. It hits it and it becomes turbulent, so you
10 don't have the capability, whatever little fiber gets
11 deposited on the surface of the neck and doesn't
12 transpose down.
13 MR. SMITH: Okay. I have a few photos
14 just showing some quantities of, you know, what came
15 through and without the --
16 CHAIRMAN WALLIS: That's quantity, or
17 that's just a sample?
18 MR. SMITH: No, this was the quantity.
19 CHAIRMAN WALLIS: That's the quantity.
20 MR. SMITH: Yes.
21 CHAIRMAN WALLIS: So we should look at the
22 quantities and compare them here.
23 MR. SMITH: Yes. Yes. This is just a
24 quantity. This is before and after. It does a pretty
25 nice job. And the big thing is --

1 CHAIRMAN WALLIS: But the engineering
2 question is: can you predict it?
3 MR. SMITH: You --
4 CHAIRMAN WALLIS: How much do you need to
5 catch before there's a problem downstream? And all
6 those kinds of questions.
7 MR. SMITH: We're still working with fuel
8 lenders on determining what the limitation is
9 downstream. And the thing to note is that this stuff
10 is more powdery form. It's more closer to that of a
11 particulate versus that of a --
12 CHAIRMAN WALLIS: But the screens that
13 you're installing in plants have this bypass
14 eliminator in them?
15 MR. SMITH: Yes, sir.
16 Again, we show some of the -- some of the
17 material being strapped -- trapped on the surface of
18 our knitted mesh material. The things -- this is some
19 of our --
20 CHAIRMAN WALLIS: I would think that the
21 chemical precipitants that they go through would
22 actually make a nice, thin bed on that bypass
23 eliminator.
24 MR. SMITH: Most all -- all particulate
25 has passed right through this in the past, and I know

1 recently it was passing right through it. At one
2 point it was --
3 CHAIRMAN WALLIS: Even after a bed begins
4 to form on the bypass eliminator?
5 MR. SMITH: Oh, no, by itself.
6 MR. ZIGLER: By itself. There was a test
7 that was conducted with the bypass eliminator and
8 chemical precipitants --
9 MR. SMITH: Yes.
10 MR. ZIGLER: -- with the WCAP chemical
11 precipitants by itself with no fiber, and there was no
12 head loss increases.
13 MR. SMITH: Yes, it was passing right
14 through. What we've seen -- this is, you know, some
15 of our data at this point in time. We've seen
16 standard perf plate, and the perf plate holes for our
17 -- our strainers have been in the 3/32 size perforated
18 plate hole with about a 27 to 30 percent open area.
19 We've got fibers ranging from around one
20 micron to three -- excuse me, 1,000 microns to 3,000
21 micros in length. It's kind of a little ball, little
22 puffs of stuff, and a little clumping going on. When
23 we run with our secondary filter we get 80 to 90
24 percent, based upon our observation -- and this is
25 using a microscopic evaluation. Less than five

1 microns, almost all are shorter than 1,00 microns, and
2 it's displaying more of a particulate nature.
3 And we're using -- we're going after this
4 as if it is particulate in nature, and many people are
5 trying to approach this -- if it is particulate, it
6 won't bridge, it will pass through and pass through
7 downstream components that are -- we're concerned with
8 the fiber actually getting in there and bridging.
9 And that I believe is the success path
10 we're trying to get through here, is if you can show
11 these things are short enough in length that they
12 don't -- they transform from being a fiber material
13 into that of a particulate material.
14 CHAIRMAN WALLIS: Those 3,000 microns, is
15 that three millimeters?
16 MR. SMITH: Three millimeters, yes. I
17 mean, they're short, eighth inch. And then we get it
18 down -- we're running really short here, so -- and
19 that's the end of our slide show.
20 MEMBER MAYNARD: Quickly going back to the
21 module design, that feeds into a manifold. The water
22 then goes from there to the sump?
23 MR. SMITH: Yes. Yes, sir.
24 MEMBER MAYNARD: And I'm assuming that
25 that's a gravity flow, and these are put in in a way

1 where that offload --

2 MR. SMITH: We're all submerged at this

3 point, and so it is fully submerged. It is not

4 gravity, but you are all below the water level at this

5 point, and it's the head of the water driving it, you

6 know, to your pump located, you know, at a lower

7 elevation. And so -- and then, we run through the

8 calculations for internal losses and strainer head

9 losses.

10 CHAIRMAN WALLIS: So this is a very

11 interesting, descriptive presentation. It's not

12 really an engineering presentation. I mean, you

13 haven't said, "Here are the functional requirements

14 and specifications for a particular plant. Here's the

15 kind of debris that we handle. Here's the head loss

16 tolerable. Here are the various conditions throughout

17 the event, temperature and so on and so on. Here's

18 the chemistry. Here is our design. And here is the

19 proof that we're confident that it will work, because

20 we have adequate data and we have adequate means of

21 extrapolation and adequate means of predicting flow

22 patterns in the plant, and so on."

23 There's a tremendous amount of stuff in

24 the engineering of this that you haven't told us about

25 at all.

1 MR. SMITH: When we were putting this
2 presentation together, we asked, you know, what agenda
3 to present. And we had an agenda from our past --
4 CHAIRMAN WALLIS: Yes, but I'm just
5 wondering if it exists.
6 MR. SMITH: We have a lot of -- yes, we do
7 -- go ahead, Gil.
8 MR. SMITH: In the end of everything,
9 you're absolutely right, Dr. Wallis. We have what we
10 call the strainer certification calculation. And this
11 is where everything feeds in. This is where we come
12 in with our composite curve that you saw on it, what
13 we can then predict from that one using the 6224,
14 which is pretty decent, incidentally, from a
15 particulate standpoint, to extrapolate given
16 parametrics of energetics and cotese failed, cogene,
17 parametrics from CalSil, etcetera, etcetera, to
18 provide the client with not a single data point but
19 with a range of values that he can certify that that
20 strainer will work over a large range of events.
21 CHAIRMAN WALLIS: So when I'm up there
22 making a presentation to the Commission and some
23 Commissioner says is it my opinion that you guys are
24 really on top of the engineering and these things will
25 work, I just have no -- nothing to say, because I

1 haven't seen anything. And just say they've described
2 what they've been doing to me, but I have no idea
3 whether it's going to work or not.
4 MR. SMITH: We have data that show it's
5 working.
6 CHAIRMAN WALLIS: You have it, but I
7 haven't seen it.
8 MR. ZIGLER: We would be glad to show that
9 to you, but it just --
10 CHAIRMAN WALLIS: Maybe we need another
11 meeting. Maybe we need a technical -- we need another
12 technical meeting of some sort.
13 MR. SCOTT: Can I interject something?
14 Mike Scott, NRC staff. You all are -- as all of you
15 are currently in progress on this, right, you have not
16 identified the success path yet that gets you to the
17 end result that he's asking for.
18 MR. SMITH: Not for every topic, that's
19 correct. We're still wrestling with that.
20 MR. SCOTT: So had you been asked to come
21 in and provide that solution path, you're not prepared
22 to do it yet, and I'm assuming nobody is yet. We're
23 still working on this and are going to be for sometime
24 yet in the future.
25 MR. SMITH: We have partials and pieces,

1 you know. We tried --

2 MR. SCOTT: Right.

3 MR. SMITH: -- to get through, you know,

4 the classical testing of head lossing -- head loss

5 testing, but to say we've bounded everything here, no.

6 CHAIRMAN WALLIS: We are usually asked for

7 our judgment on things and whether things are going

8 the right way and are you on the right track, and are

9 you solving the problem, and so on. And I can say,

10 yes, this description of stuff looks very interesting.

11 I mean, you're doing stuff which sounds as if it's

12 relevant. But I can't say much beyond that, because

13 I haven't seen technical results from it.

14 MR. SCOTT: And the staff is not ready to

15 reach a conclusion yet as to whether this will pan out

16 without an additional set of actions to be taken.

17 It's going to likely be iterative. And so, you know,

18 six months, a year from now, we're obviously going to

19 have a much better idea as to what's needed. But

20 it's --

21 CHAIRMAN WALLIS: Everybody is going to be

22 iterative on these chemical effects, because they've

23 been showing more clogging than was desirable.

24 MR. ZIGLER: I go back to my opening

25 slide, Dr. Wallis. Okay? We are looking at every

1 single step along the way --

2 CHAIRMAN WALLIS: I understand that.

3 MR. ZIGLER: -- and we -- when we stumble,

4 we go back. And as I mentioned before, when we're

5 talking about the chemical issue over here we're

6 stumbling right down here. So we're now going back to

7 debris generation and doing chemical debris

8 generation, which is something which we haven't done

9 before.

10 CHAIRMAN WALLIS: This is your plan of

11 campaign. But until you actually fight the battle, we

12 don't know if it's going to work.

13 MR. ZIGLER: Absolutely. Eventually we'll

14 -- going through those do loops many times we'll

15 eventually --

16 CHAIRMAN WALLIS: I understand that.

17 MR. ZIGLER: -- come down over here.

18 CHAIRMAN WALLIS: Right. I understand

19 that.

20 MR. SMITH: Yes, and we've gone through

21 those do loops with several types of classical

22 insulation debris that many clients cannot -- you

23 know, the strainer system could not tolerate it. And

24 in many cases, they have gone -- had to go back and

25 remove certain types of insulation material in their

1 plant. So we've gone through this do loop on a couple
2 issues already.
3 MR. ZIGLER: Whether it's reducing debris,
4 putting in debris interceptors, etcetera, etcetera,
5 etcetera. But we have had campaigns, but the war is
6 not yet finished.
7 MR. SMITH: Right. We've had little
8 battles, but --
9 MR. CHOROMOKOS: One last thing. I mean,
10 we came here with the intent of informing you of the
11 activities we're doing to address it. We didn't come
12 here with all of the addresses.
13 CHAIRMAN WALLIS: I understand that.
14 MR. BUTLER: Dr. Wallis, I'd also like to
15 point out that some of the details that you're looking
16 for are really the licensee's details. Intercon and
17 the other strainer vendors are contractors to the
18 licensees. If you're looking for that detail, we
19 really have to pursue getting the plants themselves to
20 present with their contractors.
21 MR. SCOTT: But not at this stage. It's
22 still premature for that.
23 MR. BUTLER: Correct.
24 MR. SCOTT: Because the battle is still
25 being fought, as was said.

1 CHAIRMAN WALLIS: Okay. Well, maybe we
2 can ask the staff when they get up there how far along
3 they think things have come.
4 Do we have any more questions? I notice
5 it's time for our break. Ready to move on, have a
6 break? Okay.
7 MR. ZIGLER: And, you know, if you're ever
8 interested in seeing some of those tests, you're
9 welcome to participate.
10 MR. SMITH: Yes. We have several tests
11 scheduled for this fall, and so you all are welcome
12 to --
13 MR. CARUSO: Is the staff observing your
14 chemical effects testing?
15 MR. SMITH: They just did this past week.
16 MR. ZIGLER: Thursday and Friday they were
17 there.
18 MR. SMITH: Yes.
19 CHAIRMAN WALLIS: Okay. Well, Gil, Aaron,
20 Rob, thank you very much. We will take a break.
21 We'll take a break until 10 minutes to 11:00.
22 (Whereupon, the proceedings in the
23 foregoing matter went off the record at
24 10:34 a.m. and went back on the record at
25 10:53 a.m.)

1 CHAIRMAN WALLIS: Okay. Please come back
2 into session. Apparently we gained about an hour on
3 the previous presentation. Maybe we need to -- maybe
4 they can come back and give us data, then, in that
5 case.
6 We're looking forward to a presentation
7 from AREVA on this same topic. You have two hours
8 scheduled, but we'll see how it goes. We'll take a
9 break for lunch, if you need that much time.
10 MR. WILLIAMS: Okay.
11 CHAIRMAN WALLIS: Probably will. So we'll
12 probably interrupt your presentation. Maybe if we get
13 to a good point we'll -- you can point out to me or
14 I'll point out to you that we should take a break for
15 lunch. Go ahead.
16 MR. WILLIAMS: My name is Lee Williams.
17 I am the General Manager of Plant Engineering for
18 AREVA in the U.S. AREVA, for those that don't know,
19 is the former Framatome ANP.
20 Appreciate the opportunity to be here this
21 morning. I want to introduce my team. We have a team
22 put together including ourselves, and we do primarily
23 engineering. Alden Laboratory, represented by Dr. Stu
24 Cain on my left, is where we do the testing, and also
25 on my left, Jim Bleigh from Performance Contracting,

1 who does the strainer design itself and the
2 fabrication of the strainers. And we'll show you some
3 of those pictures as we go forward.
4 Also with me is Ken Greenwood, who is my
5 technical lead in AREVA. So we'll be sharing in this
6 presentation.
7 Just a couple of opening remarks. This
8 team that is put together -- we have done work -- we
9 were in this issue back in the BWR days back in the
10 middle '90s. And we've been heavily involved in the
11 upfront engineering for the PWRs as the previous
12 presentation talked about the generation, transport,
13 all facets of this, all the way through strainer
14 design and now up to installation and subsequent
15 followup testing.
16 One thing I want to point out is that, you
17 know, as we went forward many of the clients that we
18 had wanted to move forward to -- in order to meet the
19 NRC dates. So as things were developing, we were
20 developing test protocols and, as you will see, our
21 test protocol in some cases has evolved based on our
22 own client input, the NRC interaction which we've had
23 quite a bit of during the process, and our own
24 experiences and our own discoveries.
25 CHAIRMAN WALLIS: Excuse me. Because of

1 the Framatome connection the French have had a lot of
2 experience with putting in bigger screens. Does this
3 give you a leg up in the work? Were you able to rely
4 on data and the design methods, and so on, from
5 France?
6 MR. WILLIAMS: Well, I mean, even at this
7 time EDF is actually increasing their screen sizes as
8 -- you know, usually it's the same kind of methodology
9 criteria that's being used in the U.S. We didn't
10 really have a lot --
11 CHAIRMAN WALLIS: I think they started it
12 before we did, though, didn't they?
13 MR. WILLIAMS: It's very much -- about a
14 year earlier I think.
15 CHAIRMAN WALLIS: So you should have a leg
16 up on the competition here.
17 MR. WILLIAMS: Well, sometimes the
18 information is not directly applicable, as you well
19 know from France to the U.S. We did have some
20 information, but nothing that really I think --
21 actually, as we got into it, I think we ended up
22 getting more information rather than direction, to be
23 perfectly honest with you.
24 And I think one of the things we want to
25 emphasize here as before -- the resolution of this

1 issue needs to be addressed from a big picture
2 standpoint. It's got to be looked at in the
3 conservatisms as there are assumptions being made.
4 The testing approaches that are being used, the size
5 of screens that are being installed, very much like we
6 did with the boilers, and you'll see some references
7 to some protocol and decisions we made that basically
8 grew out of what was done and acceptable for the BWRs.
9 One of the things we want to note here
10 just very quickly, this is for the benefit of our
11 clients that we -- they were a little concerned about
12 the -- you know, we are representing a series of
13 clients of about 15 units. This information is
14 submitted for the information for the ACRS and the NRC
15 staff, but specific information on a plant basis
16 really is the responsibility of the licensee.
17 General topics -- and I don't know -- I
18 apologize up front, we -- we have set up our
19 presentation, Dr. Wallis, very much like the previous
20 one.
21 CHAIRMAN WALLIS: Well, let's go back to
22 the previous questions here. You say that it's all
23 the responsibility of the licensees to make their
24 case, which is true. But presumably you've set up an
25 engineering base which enables them to make their

1 case.

2 MR. WILLIAMS: That is -- that is very

3 true.

4 CHAIRMAN WALLIS: That base has to be

5 validated and accepted and believed and so on. Once

6 that's done, then maybe it's easy for the licensees,

7 or much easier.

8 MR. WILLIAMS: Well, you have to

9 understand there is many aspects of this that come

10 into play. And not one vendor for one plant is really

11 handling each aspect. In other words, what I mean was

12 you have one group that did generation transport,

13 somebody else may be doing the screen design and

14 installation, somebody else may be doing bypass. So

15 it -- there is --

16 CHAIRMAN WALLIS: There are different

17 consultants or vendors or something like --

18 MR. WILLIAMS: Yes, absolutely.

19 MR. GREENWOOD: I think it's important --

20 this is Ken Greenwood, AREVA. It's important to note

21 I think this -- the purpose of this, too, is more

22 directed towards the data tables later in the

23 presentation.

24 MR. WILLIAMS: As I started to say, we

25 have set this up as a -- to focus more on the testing

1 with some overall general information previous to the
2 -- similar to the previous presentation, so your
3 comment about lack of data may obviously apply to us
4 also.
5 CHAIRMAN WALLIS: Well, there's going to
6 be a prize for whoever comes up with some data in
7 these presentations.
8 MR. WILLIAMS: Well, we have some data and
9 a couple of tables we'll walk you through. We'll go
10 from there.
11 Starting off with a facilities overview
12 for the test, Stu Cain will walk us through that.
13 MR. CAIN: Stu Cain, Alban Research
14 Laboratory. I'll just walk you through our test setup
15 very briefly. The flume setup that we have, you can
16 see on the right-hand side here a little bit better in
17 your handout. We have a flume that's 2.25 feet wide,
18 3-1/4 feet tall by almost 21 feet long. We have a
19 flow capacity that is a calibrated flow capacity of 10
20 to 120 gpm, and our pump is capable to a maximum of 30
21 feet of head. So we can go up to relatively high
22 heads.
23 We have return flow options for this loop.
24 A couple different options exist. We can return flow
25 directly to the upstream end of the flume. We can

1 also divert the flow to overhead spray nozzles. Now,
2 those overhead spray nozzles were designed to provide
3 agitation to the flume, provide kinetic energy to
4 suspend the material in the flume.
5 CHAIRMAN WALLIS: And they don't get
6 clogged up by bypass debris?
7 MR. CAIN: They do not, no. No. We have
8 a sufficiently large hole diameter on the nozzle. We
9 can change nozzle diameters. We can change the
10 vertical fall height of the water. We can also
11 submerge the nozzles to achieve different energy
12 levels.
13 CHAIRMAN WALLIS: Pretty cold water for a
14 sump.
15 MR. CAIN: Well, it's actually city water.
16 And if you saw our laboratory, you would realize
17 there's quite a stretch underground that the water has
18 to flow through to get to our facility.
19 Strainer pressure differentials were in
20 the range of about .02 feet to 12 feet, and, as you
21 said, the water temperature was 40 to 70 degrees
22 Fahrenheit.
23 Go ahead, Lee.
24 CHAIRMAN WALLIS: And when you do tests at
25 -- over this range of temperatures and then you apply

1 them to a sump at 200 and something, now there has to
2 be an equation or something which tells you how do you
3 take account of the changes in viscosity and --
4 MR. CAIN: Yes.
5 CHAIRMAN WALLIS: So you use supply design
6 equations, then?
7 MR. CAIN: Yes. This is a picture of the
8 test facility. I'll just point out a few things on
9 this slide. This is the flume here. It's elevated
10 because we can run a couple different types of
11 configurations. We have a pit configuration or a
12 depressed sump configuration here.
13 We can mount off the back wall. We can
14 also mount vertically in the system. These are the
15 overhead spray nozzles. This is the overhead spray
16 manifold. This is the return piping. So we can send
17 it through a couple of different orifice plates here
18 for flow measurement back up to the spray nozzles or
19 to the front end of the flume.
20 CHAIRMAN WALLIS: These are all two by
21 fours that are holding it up?
22 MR. CAIN: It is, yes. Structurally
23 designed, of course.
24 MR. WILLIAMS: And we've had loading
25 conditions where we've had to reinforce the --

1 CHAIRMAN WALLIS: So you've gone away from
2 angle iron and all those kind of things. This seems
3 to be going back to the '30s or something.
4 MR. CAIN: Well, this flume actually is a
5 fairly old facility. It was pre-BWR testing. And
6 when we did the pit configuration we needed to raise
7 it up. It was on the floor originally, on
8 cinderblocks. Right here you can see -- and we'll
9 show pictures later on -- this is the location of our
10 bypass sampling. We have three isokinetic bypass
11 sampling ports where we can pull off bypass samples.
12 MR. WILLIAMS: One of the original
13 thoughts in building the flume, Dr. Wallis, was that
14 we were looking at the differences between BWRs and
15 PWRs, and one of the significant things we saw in many
16 of the plant configurations, that around the area of
17 the sump was a fairly quiet pool because of the, you
18 know, flows. And, therefore -- and you'll see the
19 range of flows that we're dealing with all the way
20 from 2,000 gpm to 19,000 gpm at the onset of recirc.
21 One of the original thoughts was, how much
22 credit can we take for the settling in and around the
23 closed-in area of the sump itself? And so our initial
24 test we had -- we were moving the -- started with the
25 debris somewhat spread across there, but as we got

1 input, not only from the NRC staff but looking at the
2 conservatisms with our client, we later -- the latest
3 test had the debris all moved up towards the strainer
4 itself as well as the -- as Stu said, the agitation of
5 those downward jets keeping things suspended.
6 So we -- the test methodology evolved,
7 because there really wasn't a standard protocol
8 established similar to what the BWRs had. So we -- we
9 evolved it and got better as we learned.
10 MR. CAIN: Just a couple of photographs of
11 strainer mountings in the flume. This is a pit
12 configuration, so this is a single module, and this is
13 -- you're looking at in a plan view. This is the pit
14 in here, and it's sitting down inside the pit.
15 MR. WILLIAMS: This is the floor level of
16 the flume itself, and this is to simulate the closed-
17 in edges of a pit configuration. You can see that the
18 -- Jim, you might want to take a minute and describe
19 what the module is, so Dr. Wallis has an understanding
20 of that.
21 MR. BLEIGH: Basically, we make a stacked
22 disk strainer, which is a series of nominally half-
23 inch thick disks with a face plate on both faces, a
24 disk rim around the perimeter. All of that is
25 perforated plate. They are separated by what we call

1 gap rims, which is also perforated plate, and the gap
2 rim is a larger diameter than the core tube that is
3 inside.
4 So when you see those four bolts on the
5 outside of those four bolts would be a gap rim, but on
6 the inside of those four bolts on the inside of this
7 cross and collar here is where a pipe is and a core
8 tube. And the core tube has holes in it of different
9 sizes that vary from the section end to the far end,
10 and the purpose of the flow control holes is to create
11 uniform flow along the axial length of all of our
12 strainers, so that the furthest disk from the suction
13 line is going to draw the same amount of water as the
14 nearest disk.
15 CHAIRMAN WALLIS: At least before it gets
16 debris on it, yes.
17 MR. BLEIGH: Correct. You know? But that
18 would assume non-uniform debris loading. If we have
19 uniform flow to all surface areas, we're assuming that
20 debris is going to collect, unless it's from a single
21 direction, in a uniform manner.
22 CHAIRMAN WALLIS: So these are stacked
23 disks. So a lot of the area is between these layers.
24 MR. BLEIGH: That is correct.
25 CHAIRMAN WALLIS: And if it fills up with

1 debris in there, then your approach velocity perhaps
2 should be around the whole box rather than --
3 MR. BLEIGH: Right.
4 CHAIRMAN WALLIS: -- based on the entire
5 area.
6 MR. BLEIGH: That's correct. And we're
7 testing these in both low fiber conditions where the
8 gaps are not filled in. We're also testing them in
9 completely buried submerged --
10 CHAIRMAN WALLIS: You get them like the
11 ones we saw earlier this morning, where --
12 MR. BLEIGH: Absolutely.
13 CHAIRMAN WALLIS: -- there's several feet
14 of fiber maybe above the whole thing.
15 MR. BLEIGH: Oh, absolutely.
16 CHAIRMAN WALLIS: All right.
17 MR. BLEIGH: And I think we have pictures
18 later in the presentation where we buried the strainer
19 with mixed debris of fibers and particulates.
20 MR. WILLIAMS: But to make a point that
21 you're right about the circumscribed flow here. That
22 was one of the areas -- things that we did going
23 forward, and the first plants we tested were extreme
24 low fiber plants, really circumscribed area, then
25 becoming neglected because you had no material to fill

1 in the gaps. But as we got higher fiber plants, then
2 we evolved to running a suite of flow rates, including
3 the circumscribed flow area.
4 MR. BLEIGH: And one of the interesting
5 things when we started the testing program that was
6 very limiting in terms of the size of prototype
7 modules we use is that for high fiber plants -- and
8 you might recall a year and a half ago they talked
9 about 50 pickup loads of debris going to a screen, if
10 I make the screen too large for the physical size of
11 this flume, the entire flume is filled with debris.
12 So there is a limit in terms of how large
13 a prototype can be tested based on the design basis
14 that we're using. And so, you know, there was a
15 number of variables that we had to balance to decide
16 what size screen are we going to use.
17 MR. WILLIAMS: And as Stu was saying, this
18 is giving you -- is the flexibility that we built into
19 the flume.
20 MR. BLEIGH: And, again, the flume is
21 designed to accommodate all of the plant
22 configurations, whether it be a horizontal strainer,
23 a vertical strainer that's in a pit, or a vertical
24 strainer that's actually sitting on the floor. So in
25 this flume we're able to actually test all three

1 configurations.

2 CHAIRMAN WALLIS: Well, if it works with

3 this -- when it's buried in fibers, then, really, the

4 details of this are less -- become less important --

5 MR. BLEIGH: That's correct.

6 CHAIRMAN WALLIS: -- as it's flowed

7 through all that fiber that's --

8 MR. BLEIGH: That's correct.

9 CHAIRMAN WALLIS: -- covering everything.

10 You have all this area. Is that really because of

11 those thin bed effects, or something? Or why do you

12 need all of the area?

13 MR. BLEIGH: Absolutely. The --

14 CHAIRMAN WALLIS: You only need it when

15 you have the thin layers on it, right? And chemical

16 effects or something. But once you're into the

17 submerged thing, it's a completely different regime.

18 MR. BLEIGH: Yes, that's correct. It's a

19 completely different --

20 CHAIRMAN WALLIS: You wouldn't need to

21 have all of this area, presumably.

22 MR. WILLIAMS: I think we have to go back

23 to the evolution of how decisions were being made as

24 we went forward to start the test program. In many of

25 the plants, they look at not only -- you look at a

1 calculation of 6224 based on their debris loads, but
2 they also looked at space available.
3 Several of our plants said basically,
4 "Here's the footprint. Fill the space with as much
5 surface area as you can get, and we will basically
6 back our way into the solution."
7 CHAIRMAN WALLIS: So when you say 7,000
8 square foot of surface area, that's all the holes and
9 all these plates. How does that compare with the sort
10 of superficial area of the box?
11 MR. BLEIGH: It depends on the plant
12 design, because the larger the disk design, then the
13 difference in that ratio -- if it's not a large --
14 CHAIRMAN WALLIS: It must be something
15 like an order of magnitude, isn't it?
16 MR. BLEIGH: No, it's not that bad.
17 CHAIRMAN WALLIS: It's not that bad?
18 MR. BLEIGH: No, it's like maybe twice.
19 CHAIRMAN WALLIS: Only that?
20 MR. BLEIGH: Right. I mean, you lose two
21 or three times. Again, it depends on the plant
22 arrangement.
23 MR. WILLIAMS: And it depends on the -- in
24 some plants we have an array arrangement, which is
25 over the sump pit itself. And then some plants, as

1 you -- similar to what you saw earlier, that had the -
2 - had a small area, and didn't have a sump pit at all,
3 and then we ran the strainers out around the crane
4 wall.
5 MR. BLEIGH: And as was mentioned in the
6 previous discussion, the flow ratio of these screens
7 are extremely slow. I mean, it's almost stagnant
8 water, you know, in and around the screen areas. And
9 so you don't get compression of the debris bed, you
10 know, near the screens.
11 MR. GREENWOOD: Okay. This slide here
12 shows what Jim is mentioned. Ken Greenwood, AREVA.
13 The plant design flow rates that we're dealing with
14 covers the -- illustrates the large disparity of plant
15 conditions that we had to deal with.
16 Plant design flow rates, as Lee had
17 mentioned, from 2,000 to almost 20,000 gpm. Approach
18 velocities -- excuse me, the screen approach
19 velocities were very low based on the large square
20 footage of the new plant screens. Again, you can see
21 the large range there. And the hole diameters, just
22 to make things consistent, roughly 3/64 to 3/32.
23 The testing parameters, which represent
24 the prototypes which were tested, flow rates were
25 scaled down based on the screen surface area, show 15

1 to 120 gpm, and the screen approach velocities here
2 are the same. Those were the intent of the scaling
3 was to -- to maintain the screen approach velocity.
4 So the area was based on debris loads and
5 other physical configurations, and then the flow rates
6 were determined based on maintaining consistent
7 approach velocities.
8 CHAIRMAN WALLIS: You are testing
9 essentially one module out of many modules, is that
10 what you're doing?
11 MR. GREENWOOD: That's correct.
12 MR. WILLIAMS: What would be done, Dr.
13 Wallis, is that we would come up with a preliminary
14 screen size that would go in the plant. And based on
15 that surface area and the plant flow rates at the
16 onset of recirc, the maximum flow rates, we would
17 establish a screen approach velocity, and then use
18 that as a scaling factor, and have that same approach
19 velocity in the flume test setup.
20 MR. GREENWOOD: Just one last thing on
21 that. The strainer hole diameters were also
22 maintained to the prototypes.
23 MR. WILLIAMS: That's correct.
24 MR. GREENWOOD: This is the list of
25 licensees that we're working with, the current status.

1 We've got six units fabricated and delivered. Nine
2 units are in fabrication now, and we actually have one
3 plant installed. And you'll see some pictures of that
4 later in the presentation.
5 MR. WILLIAMS: And we actually began
6 testing -- because of the schedule that many of these
7 plants had, some of these were starting to install as
8 early as this spring, with several of them this fall.
9 We started the test setup in late October/November
10 last year. Actually, in September.
11 MR. GREENWOOD: These are some of the
12 parameters that we found that affected the head loss
13 during the testing. I think you've heard about some
14 of this before. One of the things that maybe you
15 haven't heard was the overhead nozzles. Again, here,
16 this was our intent to keep the debris in suspension
17 as much as possible without introducing enough energy
18 to actually dislodge debris from the strainers
19 themselves.
20 CHAIRMAN WALLIS: When it says "debris
21 mix," it's also how you put it in, isn't it? I mean -
22 -
23 MR. GREENWOOD: Yes.
24 CHAIRMAN WALLIS: -- and the order in
25 which you put it in, and things like that, can make a

1 difference.

2 MR. GREENWOOD: Yes. We have a slide to

3 address that. Next one?

4 Some of the observations early on -- the

5 tests included some of the miscellaneous type debris

6 of tags and labels, RMI, paint chips.

7 CHAIRMAN WALLIS: Where do they go?

8 MR. GREENWOOD: They just settle to the

9 floor.

10 CHAIRMAN WALLIS: Settle to the floor,

11 okay.

12 MR. GREENWOOD: Yes.

13 MR. BLEIGH: And they don't appear to have

14 width velocity to come up. They just go down and stay

15 down.

16 MR. GREENWOOD: Even when dumped

17 practically on top of the strainer, it just passes by

18 to --

19 MR. WILLIAMS: I'll show you a couple of

20 pictures. We actually forced -- we did some testing

21 on paint chips in a low fiber condition, and the only

22 way we could get it to the strainer is actually

23 physically dump it and then shovel it onto the

24 strainer. It would not pick it up.

25 MR. GREENWOOD: The 6224 correlation was

1 a bounding -- in many cases used some of the initial
2 designs, and testing ones corrected for temperature
3 came in well below that.
4 CHAIRMAN WALLIS: This is because of non-
5 uniform distribution, presumably, rather than because
6 the correlation is way off? Or is the correlation way
7 off --
8 MR. WILLIAMS: I think it is the
9 correlation that is developed based on flat plate
10 information, and now you've got complexity, a lot of
11 hydraulics going on in and around the strainer itself
12 that doesn't --
13 CHAIRMAN WALLIS: I think it must be non-
14 uniform distribution, then, because if you have this
15 stuff uniformly distributed -- these are almost flat
16 plates you have. They're disks. They're almost --
17 MR. GREENWOOD: Correct. I think the
18 difference is 6224 wasn't a vertical loop. Here
19 you've got the effects of gravity which can keep
20 debris away.
21 CHAIRMAN WALLIS: You'd expect it to be
22 reasonably uniform. You've probably got some
23 flowthrough or whatever you call it -- you know,
24 bypass the holes through the fiber bed and stuff and -
25 -

1 MR. BLEIGH: But in many of our thin fiber
2 bed tests, the screen is completely covered. We have,
3 you know, not perfect, but we have coverage of fibers
4 everywhere.
5 CHAIRMAN WALLIS: But you would expect
6 this correlation to do not too badly.
7 MR. BLEIGH: I think it's because of the
8 low flow rates and the fibers just not compressing
9 against the screen. It's at the screen, but it's not
10 compressing.
11 MR. GREENWOOD: We're at the very low end
12 of the 6224 correlation.
13 CHAIRMAN WALLIS: They have predictions
14 for no compression, too. It's probably in the laminar
15 region, isn't it? It's very, very --
16 MR. GREENWOOD: Very much so.
17 CHAIRMAN WALLIS: So it should be linear.
18 It should be very straightforward.
19 MR. GREENWOOD: And the other thing is
20 that the amount of debris that you would put in for
21 the correlation would assume 100 percent accumulation.
22 In this case we would have much of the debris drop to
23 the floor below the strainer.
24 CHAIRMAN WALLIS: You'll have to have Gil
25 look at why the NUREG didn't work, since he's the

1 first author on it.

2 MR. WILLIAMS: It works.

3 MR. GREENWOOD: And one last slide for me

4 is the geometry. This is some things that Lee had

5 alluded to before. Our testing protocol evolved over

6 the course of testing. You mentioned the debris

7 placement, use of overhead nozzles, which nozzles to

8 use and at what elevation to place the discharge,

9 again depended on -- a lot of that came from

10 experience as well as observations from the staff and

11 clients. But in the end, our maximum head losses seem

12 to be fairly consistent.

13 MR. WILLIAMS: We actually did some

14 sensitivities utilizing the change in debris placement

15 and flow rates and a couple of series of tests. We

16 found we got fairly consistent maximum head losses,

17 but as you might expect debris placement will

18 obviously have an effect on the time it took to get to

19 that maximum head loss.

20 CHAIRMAN WALLIS: So what are you going to

21 give the licensee for a correlation? This NUREG-1 is

22 very conservative. Do you have an AREVA correlation

23 or something? What are you going to give the licensee

24 to use as a design tool?

25 MR. BLEIGH: We're giving them the

1 measured debris head loss, and we're showing how that
2 correlates to a NUREG calculation. And it's really up
3 to the licensee to decide, you know, how they want to
4 use the correlation and the two data points.
5 CHAIRMAN WALLIS: Is it far from the
6 correlation?
7 MR. BLEIGH: In some cases it is.
8 CHAIRMAN WALLIS: So they may wish to use
9 the data rather than the correlation.
10 MR. BLEIGH: That's --
11 CHAIRMAN WALLIS: Or will you develop a
12 new correlation that goes through the data or
13 something?
14 MR. BLEIGH: I think that many of the
15 licensees are looking at the NUREG calculation as the
16 bounding condition for the plant. And so the testing
17 becomes confirmation that the calculation using NUREG
18 is bounding and conservative.
19 CHAIRMAN WALLIS: And the interesting
20 situation will be when they find that the conservative
21 one gives them too much pressure drop.
22 MR. BLEIGH: No, it is not.
23 CHAIRMAN WALLIS: It doesn't.
24 MR. GREENWOOD: I mean, as far as the
25 margin is concerned, we're given -- our clients have

1 given us -- you're allowed so many feet without
2 getting into the details of --
3 CHAIRMAN WALLIS: Based on the NUREG.
4 MR. GREENWOOD: No, no, based on the NPSH
5 calculations.
6 CHAIRMAN WALLIS: Yes, but then whether or
7 not it's there is based on the NUREG calculation and -
8 - as I understand it, and you're showing that your
9 data all lie below it. Therefore, this is a --
10 MR. BLEIGH: As an example, if we have two
11 feet from the client, and we add together clean
12 strainer head loss component to the debris head loss
13 calculation using NUREG-6224, maybe that's 1.5 feet.
14 CHAIRMAN WALLIS: But you measure as .2
15 feet or --
16 MR. BLEIGH: And what we measure might be
17 .5 or 1 foot.
18 CHAIRMAN WALLIS: But the acceptability is
19 based on the NUREG. Acceptability of the design is
20 based on the NUREG, and you are simply showing that
21 it's conservative, it sounds like.
22 MR. BLEIGH: The testing is showing that
23 the NUREG calculation is conservative.
24 MR. WILLIAMS: But you've got to be
25 careful, because there is -- there is questions being

raised about the -- utilizing NUREG and certain, you know, particulate to fiber --

CHAIRMAN WALLIS: Right.

MR. WILLIAMS: That has to be shown in the test.

MR. BLEIGH: Which was the whole purpose of doing the confirmation testing at the plant-specific design basis.

MR. SCOTT: Mike Scott, NRC staff. As with any NUREG, the licensees are not required to use that correlation, so it's not a regulatory acceptance criterion per se. And the SER allows for different methods to be used if the licensee chooses and justifies it.

CHAIRMAN WALLIS: I think we actually had a staff presentation saying that the NUREG didn't apply to some situations.

MR. SCOTT: It's not a comprehensive, perfect correlation, certainly.

MR. BLEIGH: Based on the limitations of its initial research and development.

CHAIRMAN WALLIS: Okay.

MR. WILLIAMS: Going on with some basic protocol information, the temperature, as you noted earlier, Dr. Wallis, was ambient temperature used for

1 the test. And we would then do an evaluation to get
2 the corresponding viscosities, and the perfect
3 temperatures at the plant were outlined to us.
4 Again, many of these items that we've done
5 is completely consistent with how the BWR strainers
6 were tested and qualified.
7 I mentioned earlier that the scale
8 fraction forward of the test debris and test flow was
9 a function of the ratio of the strainer surface area
10 to the plant strainer surface area, where we would
11 maintain based on the flow rates in the flume a
12 consistent strainer flow velocity.
13 We also noted earlier we did some
14 sensitivity tests. Many of the tests had actually
15 used circumscribed flow area, but we did sensitivities
16 at higher flow rates also, just to determine what some
17 of the varying conditions would be.
18 Debris preparation -- this simply has some
19 pictures of, as you can see, the quantities of debris
20 we're dealing with. We weighed the debris dry. All
21 the insulation, both fibrous and RMI, was chopped,
22 cut, segregated, you know, in many different ways. In
23 many cases we even used -- put some through a food
24 processor.
25 Water was added. We mechanically mixed,

1 as you can see over on -- over on the right-hand side,
2 and we'll talk a little bit about some of the
3 surrogate material we utilized as was previous -- in
4 the previous presentation. We were very careful about
5 that based on size, density, and, you know, again,
6 precedent with some of the other BWR evaluations.
7 One in particular was a substitute for the
8 zinc primer, because we were testing at Alden
9 Laboratories in Massachusetts where the EPA has deemed
10 zinc a hazardous material, and it was extraordinarily
11 difficult to try to dispose of. So we came up with a
12 tin powder surrogate based on an evaluation between
13 that and the zinc primer.
14 Sequencing -- as you mentioned, it is an
15 important aspect. We came up -- again, this evolved
16 over some period of time in terms of the order of the
17 debris. One of the things we didn't want to do is put
18 the RMI -- put the fibers in and then throw the RMI on
19 top, and that basically would then trap a whole lot of
20 fibers that couldn't -- that wouldn't have the
21 opportunity to make it to the screen.
22 So what we came up with was this type of
23 just a fundamental order, we would mix these
24 constituents separately and thoroughly with mechanical
25 mixing in drums, and then add the material. And as

1 you'll see from our data chart, as I said, the first
2 couple of tests we spread it out fairly uniformly, and
3 then subsequent tests we either put it between one and
4 three feet in front of the strainer itself or actually
5 on the strainer in many cases.
6 But we put the RMI in, put all of the
7 particulates in separately, and even if you put it
8 near the screen, as you know the particulates will
9 tend to scatter. Fibrous material would be next, and
10 the latent fiber would be added, and then what we were
11 using for chemical precipitants -- we'll talk about it
12 a little bit later, but we -- in the beginning of the
13 test, while the WCAP was being developed, we were
14 utilizing manufactured chemical materials based on the
15 ICET outputs. And we subsequently evolved to
16 balancing those against the WCAP methodology, and
17 we'll talk more in detail about what's going on there.
18 CHAIRMAN WALLIS: Well, suppose you're
19 doing particulate on fibers. You throw in all the
20 particulates, and you're running the test, and it's
21 going through the --
22 MR. WILLIAMS: At this point, when we
23 first add the test it is not running.
24 CHAIRMAN WALLIS: Not going through the
25 loop yet.

1 MR. WILLIAMS: It's not going through the
2 loop. We don't have --
3 CHAIRMAN WALLIS: So all this stuff is put
4 in before you -- before you start the pump? It's just
5 stirred up in there?
6 MR. WILLIAMS: Right. We layered in
7 there, and then mechanically agitated it and --
8 CHAIRMAN WALLIS: Okay. Because there's
9 another sequence where you put in the particulates and
10 run the thing around. And then, you put in fiber
11 progressively and build up a bed, and then it catches
12 the particulates. It all takes time. You haven't
13 done that sort of sequencing where you're running the
14 loop while you're putting the stuff in?
15 MR. WILLIAMS: We did -- you know, we
16 did --
17 MR. BLEIGH: Actually, it has been done
18 both ways, but we didn't see significant differences
19 in results.
20 MR. WILLIAMS: Because, you know, the PNNL
21 people had huge differences depending on the order in
22 which they put stuff in.
23 MR. BLEIGH: The order has an effect. We
24 -- you know, what we see, though, Dr. Wallis, is once
25 we put this material in, that obviously the

1 particulate gets there -- if the material is, you
2 know, right in the vicinity of the screen. And then,
3 the -- you'd then build up a debris bed gradually as
4 you continue to run the test.
5 So, in essence, though, we didn't do it in
6 a separate condition, because to be honest with you we
7 had so many constituents of material to add in here --
8 in many of these tests there was -- you saw some of
9 those barrels. There was sometimes 15 of those
10 barrels of different materials, particulates and
11 different fiber loadings, that had to be added.
12 MR. BLEIGH: I also think sequencing would
13 make a difference in a vertical pipe test as opposed
14 to an actual or more representative arrangement.
15 MR. WILLIAMS: What you see here is, this
16 was a very high fiber test, and you'll see -- this is
17 the overhead sprays. There's a mechanical mixing of
18 the debris, and you can see just huge amounts of
19 debris in some cases that, again, resulted from the
20 conservative debris generation during transport.
21 CHAIRMAN WALLIS: Now, the sump isn't
22 agitated like this in a plant. The sump is not
23 agitated like this in a plant.
24 MR. BLEIGH: No, this is -- occurs just
25 prior to starting recirculation.

1 CHAIRMAN WALLIS: So something is
2 different between this and what happens in the plant.
3 MR. WILLIAMS: Well, what we tried to
4 simulate, we knew in many cases the material had to
5 take a very torturous path to get to the sump, and we
6 knew there would be some -- there would be mixing and
7 tumbling and just a grouping of the materials before
8 it got to the sump, because it -- the material was not
9 right at the sump, you know, independently. So we
10 knew there was some mixing going on with the -- based
11 on the CFD analysis we ran in several units.
12 MR. GREENWOOD: One of the things that we
13 did there, too, was -- is that because you put in the
14 debris in sequence, by the time you got to the last
15 item you already had a large amount of the material
16 settling, because the pumps were not running. So an
17 attempt just prior to starting those pumps to lift the
18 fibers and things up to make them more susceptible to
19 being captured by the strainer itself, was one of the
20 main reasons for this mixing.
21 MR. WILLIAMS: And, again, the debris
22 introduction, we only use this protocol for the 3 to
23 15 feet in the first test series. Afterwards we went
24 within three feet of the strainer. And actually, in
25 the first test series on the 3 to 15 we did some

1 sensitivity tests where we shoveled everything that
2 was in the flume on top of the strainer at the end of
3 the test and doubled the flow to see what effect we
4 would get.
5 So we did some -- you know, we tried to do
6 some bounding and conservative assumptions while still
7 maintaining, you know, the aspects of realistic
8 behavior of what was in the plan. And, again, the
9 overhead nozzles in the later tests, one of the things
10 we actually submerged the nozzles, the nozzles were
11 originally put in in order to try to simulate a near
12 break energy in put into the area around the strainer.
13 But one of the things we had to be careful
14 about, as you heard in the previous presentation
15 there's a balance between the amount of energy you
16 impart to keep the material suspended as best you can,
17 and if you go too high then you have a possibility of
18 actually dislodging the debris bed on the strainer
19 itself. So we were balancing those two aspects of it.
20 This gives you a little bit of an idea of
21 the types and differences of material. This is in a -
22 - one of the strainers in a pit configuration. We've
23 drained down after the test, and you can see this is
24 RMI that has gotten there. These are tags and labels.
25 This is fibers. This is some -- this is MIN-K, if I'm

1 not mistaken.

2 MR. GREENWOOD: The dark material is the

3 coating surrogate.

4 MR. WILLIAMS: The coating surrogate,

5 thank you. So you can see there's -- but in the area,

6 even after drain down, there is -- you can see the

7 gravity just pulls the material away from it.

8 CHAIRMAN WALLIS: There seems to be clumps

9 of stuff hanging off the edge of the --

10 MR. WILLIAMS: There are. I mean, and it

11 does clump -- it tends to clump back up even after you

12 mechanically shred it up and put it in water. Then,

13 as it collects on the screen, it will tend to clump

14 back up.

15 MR. CAIN: And as we draw down the water

16 level, you can see as the water level is drawing down

17 the material slumping off and agglomerating as the

18 water level is brought down. So some of that -- and

19 it's catching on the support --

20 CHAIRMAN WALLIS: You're trying to clump

21 off some of this stuff, because it's gathered on the

22 outside walls, will fall down.

23 MR. CAIN: Right. This isn't indicative

24 of what the strainer would look like under the

25 operating condition. So it would be fully inundated.

1 MR. WILLIAMS: And this is in the
2 operating condition. Again, this was -- this is the
3 kind of materials that -- and quantity of materials.
4 This whole pit is completely full. The strainer is
5 down in this area. And one of the things that, you
6 know, caused us some problems from a visual standpoint
7 is that once you put in some of these particulate
8 materials that the water became so cloudy you didn't
9 have a picture.
10 In this case, there is so much material
11 covering the strainer that you can't get a
12 visualization. But this does give you an idea. All
13 of the material is basically right here. What is back
14 in this area has basically drifted there because there
15 was no driving force to keep it piled up in this area.
16 CHAIRMAN WALLIS: What's your bed
17 thickness? Your bed thickness here is several feet,
18 presumably, and it has to filter through all that
19 stuff to get to the --
20 MR. WILLIAMS: It had to be, yes.
21 MR. BLEIGH: It's anywhere from several
22 inches above the strainer, because submergings is
23 usually two or three inches, and at least it started
24 recirculation. And then, depending on whether you're
25 in front or behind the strainer or around the

1 strainer, it's a different thickness of debris bed.

2 CHAIRMAN WALLIS: So we might as well

3 design for flow through porous medium? And the

4 limiting factor here is presumably the flow through

5 all that stuff lying on top of the strainer rather

6 than --

7 MR. BLEIGH: Right.

8 CHAIRMAN WALLIS: -- the strainer itself.

9 MR. CAIN: And the higher the velocity,

10 some more of that would compress and the higher the

11 head loss you'd expect.

12 CHAIRMAN WALLIS: But it doesn't compress

13 at all in your case, does it?

14 MR. CAIN: No. Our approach velocities

15 are so low --

16 MR. BLEIGH: By controlling the flow in

17 every module, you know, we're not forcing debris to

18 compress against the shell of the screens and then

19 force that debris bed to become more blocking. You

20 know, experimentally, it would appear that there is a

21 target or a trigger point, and it can be different for

22 different kinds of debris mixes, where when you

23 finally start that phenomena of compressing the debris

24 bed it feeds itself, because once you start

25 compressing it, then it has to suck more and then that

1 forces more compression.

2 So the key is to keep whatever that

3 trigger point is of velocity at -- below a certain

4 point so the debris approaches the screen but never

5 really compresses it into --

6 CHAIRMAN WALLIS: I think it is stable.

7 You could presumably envisage something where as it

8 begins to compress the pressure drop goes up. It

9 keeps on compressing, and eventually goes -- you know,

10 it -- that would be an unstable bed, I would say.

11 MR. BLEIGH: Right.

12 CHAIRMAN WALLIS: I don't think the

13 characteristics of fiberglass are like that. And

14 usually, you increase the flow, it compresses a bit

15 more.

16 MR. BLEIGH: Right. And it has a

17 compression factor --

18 MR. WILLIAMS: That's what -- that's

19 exactly what we've seen. It's very interesting,

20 because in many of the plants we have these very high

21 fiber conditions, but we would run, you know, the thin

22 bed type test with much lower fiber. And as

23 consistent with the theory we saw and practice we saw

24 in the BWRs, we would get much higher head losses with

25 just the thin bed and the full particulate load than

1 we would in a condition like this. In many cases, a
2 condition like this gave you, you know, half a foot or
3 less of head loss.
4 CHAIRMAN WALLIS: Better to have the
5 particulate spread throughout a big --
6 MR. BLEIGH: Exactly.
7 CHAIRMAN WALLIS: -- bed than it is --
8 MR. BLEIGH: Normally speaking, the head
9 losses are better with a high fiber load than --
10 CHAIRMAN WALLIS: And as long as you don't
11 somehow get the fibers of particulates in first or
12 something, so they make their thin bed right on the
13 screen.
14 MR. BLEIGH: But it appears that because
15 of the low compression bed that particulates, because,
16 again, we're using very small micron size particles to
17 represent the particulates, they are finding flow
18 paths very easily through a non-compressed fiber bed.
19 And so they're in recirculation.
20 CHAIRMAN WALLIS: I guess the grounds for
21 concern would be something like this. If you build up
22 your fibers, and then due to chemical effects which
23 take some time you have some particulates or gels or
24 something coming along later, which make a skin on top
25 of this thing, which then really does compress it --

1 MR. BLEIGH: And I think that the key
2 point there is, are the particulates in the form of
3 small micron particles such as recirculating all of
4 the time through this test anyway?
5 CHAIRMAN WALLIS: Going right through the
6 fiberglass and everything.
7 MR. BLEIGH: It was just passing through.
8 Or is it more like a gel or a gelatinous mass it is
9 actually attaching to and staying on the surface. So
10 the form of the particulate is going to make a
11 difference.
12 CHAIRMAN WALLIS: Yes.
13 MR. WILLIAMS: This next photo, in one
14 plant's condition, and consistent with the NEI
15 guidance, if you have a very low fiber condition -- we
16 had a couple of plants that had literally no fiber
17 other than some small estimated latent fiber, so --
18 and they wanted to test a very high paint failure
19 condition potential, so we came up with a method to
20 establish paint chips, essentially developed a
21 methodology to develop the chips themselves in
22 different size ranges. But because there was no fiber
23 we tested these in the flume near the strainer, just
24 not enough vertical velocity component to get it to
25 the strainer. So at the tail end of the test we

1 essentially shoveled everything on top of the
2 strainer.
3 What you see here is the strainer is
4 essentially in this area right here, completely buried
5 in chips. And we really did not get substantial head
6 losses at all, even in that condition.
7 CHAIRMAN WALLIS: That's because they are
8 pretty stiff chips, and if they were very fluffy like
9 leaves they would sort of layer, and then they might
10 really block everything up. I think because the chips
11 are hard --
12 MR. BLEIGH: They really are. They're not
13 a very flexible chip.
14 MR. WILLIAMS: But certainly, fluid had a
15 tortuous path, even though they -- even if they were
16 hard because of the quantity they were talking about.
17 It wasn't a very easy pathway to the section line.
18 This is some of the data. And one of the
19 -- a couple of questions you may have here. The plant
20 names -- basically, we go Plant A, B, and C. I'm sure
21 that the plant clients themselves would offer which
22 ones that they would -- which category they came into.
23 But one of the things I want to point out
24 here on the test, you can see that we did a test
25 series for each one of the plants, up to five test

1 series, and there are several reasons for that. In
2 many cases, if it was high fiber, we were looking at
3 low fiber conditions as well as high fiber.
4 In many cases, because of the variation in
5 break locations, we had a couple different design-
6 based loading conditions in terms of one would be
7 particularly high in fiber, another would be
8 particularly high in, let's say, coating load or
9 something like that.
10 So we had several variations, and you can
11 see from the plant under the flow rates, the gpm, the
12 variations here, we made some -- also had some
13 conditions where we would test small break LOCAs.
14 Like in the -- in this condition, Plant B here,
15 Test 5, you can see that the flow rate is about half
16 of the first three tests. But that was because it was
17 a small break LOCA condition, and we wanted to
18 simulate that also, where they would have a lower flow
19 rate demand on the ECCS but a different debris
20 condition essentially estimated.
21 So what has this information here --
22 there's the design test flows, circumscribed test
23 flows here, and which ones we ran those on. We gave
24 a description of debris placement where it was. As
25 you can see, it's all within three to five feet in

1 most cases. In some cases -- you'll see in the next
2 one it's on top of the strainer.
3 Whether we used overhead nozzles. Over
4 here is the screen areas that were actually estimated
5 for the plant, and then the testing screen area in
6 this column. Hole sizes varied from .095, as Ken
7 said, to .045. And I'll go to the next one, which has
8 -- this is the same chart with several more units
9 listed here, so you can see the variations in screen
10 sizes and hole sizes that we've tested.
11 This is a follow-on chart with, again,
12 starting back with Plant A, B, and C. This gives you
13 some head loss results at design flow rates, and then
14 the head loss results at circumscribed flow rates,
15 average test temperature, what termination criteria
16 were utilized, and we also looked at percent change of
17 head loss at termination as a -- one of the questions
18 that we were working with the clients on as -- if you
19 have a test termination criteria, which at some point
20 you do, how do you take that data and necessarily
21 extrapolate that if you're getting even small
22 increases in head loss at the time of termination.
23 CHAIRMAN WALLIS: I'm looking at -- maybe
24 it's the next slide. You've got Plant D. Debris
25 placement is within three feet of the strainer.

1 Plant G it's on top of the strainer.

2 MR. WILLIAMS: Right.

3 CHAIRMAN WALLIS: But on H it's 3 to 15

4 feet upstream of the strainer. These are all

5 different conditions. How is the NRC going to

6 evaluate these tests when they're all different?

7 MR. WILLIAMS: Well, one of the things --

8 as I stated earlier, in the test -- I forget which

9 slide you're on here. Which one? Next one?

10 CHAIRMAN WALLIS: Why are they different

11 for different plants? I mean, the plants don't

12 deposit debris on top of the strainer or within three

13 feet or something.

14 MR. WILLIAMS: Well --

15 CHAIRMAN WALLIS: How do you pick that

16 particular number there? I mean, why is Plant G

17 different from D and H? And how do you pick 3 feet,

18 15 feet, 1 foot, on top of?

19 MR. WILLIAMS: Well, in my cases, as I

20 said, there was an evolution where we started

21 spreading debris out in the first series of tests.

22 Those are very low fiber conditions, so it really

23 didn't make much difference whether it was on top or

24 near the strainer.

25 We had questions working with the staff as

1 to, well, are you really giving too much credit for
2 gravity, because the material was settling too far
3 away from the strainer. So we began to move, you
4 know, testing material right at the strainer, and in
5 some cases we'd have a client that said, "I don't want
6 it on the -- you know, in front of the strainer. I
7 want it directly on top of the strainer." So that may
8 have been a preference for them to add even more
9 conservatism.
10 CHAIRMAN WALLIS: Well, a question I have,
11 how do you take the results, then, and use them in the
12 plant? I mean --
13 MR. WILLIAMS: Well, that's something we
14 would be working with particular clients, how they
15 take this data and apply the data --
16 CHAIRMAN WALLIS: Are the 15 feet data
17 better than the 3 feet data, better than the 1 feet,
18 or are they all the same, it doesn't make any
19 difference?
20 MR. WILLIAMS: Well, that's the thing --
21 I mentioned we did some sensitivities in terms of
22 maximum head loss to determine how much effect you
23 would have, and what we saw was a very consistent
24 total maximum head loss under different conditions.
25 Just the timing would be different. And, again, you

1 know, these are -- there are some questions. We're
2 working with clients that we may end up doing some
3 supplemental parametrics to look at some of these --
4 based on some of these results.
5 CHAIRMAN WALLIS: This looks sort of
6 whimsical, the way it varies from plant to plant. And
7 it's based on --
8 MR. BLEIGH: Well, this is not in the
9 chronological order of the evolution of the test.
10 CHAIRMAN WALLIS: As it evolved you
11 started bringing it closer to the strainer or
12 something?
13 MR. WILLIAMS: Yes, sir.
14 CHAIRMAN WALLIS: Okay.
15 MR. WILLIAMS: Yes, sir.
16 CHAIRMAN WALLIS: Go back to Plant H, and
17 put it on top of the strainer.
18 MR. WILLIAMS: We did an evaluation of
19 that plant as one of the plants that we basically --
20 you saw the picture of the coatings. That plant
21 essentially had no fiber loading and the coating load,
22 and we did do that. We didn't do it as an official
23 test. We did it as a sensitivity.
24 CHAIRMAN WALLIS: Then filled up with
25 coatings? That's the one when everything filled up

1 with coatings?

2 MR. WILLIAMS: Yes, sir. So we didn't

3 record that as part of the official test, but we did

4 a lot of sensitivities, you know, that weren't

5 necessarily official design basis tests to get some

6 information and utilized those as part of the

7 justification for why the results you see here are

8 conservative under certain plant conditions.

9 MR. BLEIGH: Basically, the concern from

10 the NRC staff after witnessing early tests was that we

11 don't see the debris collected on the screen. We're

12 seeing it in circulation and away from the screen.

13 And to address that concern we -- the testing protocol

14 changed to bring the debris at or as close to the

15 screen as we could basically get it, so that, you

16 know, the transport issues within the flume were taken

17 out of the question.

18 So it was just a change in protocol to

19 prove that even with the debris entered into the

20 system at the screen, you know, we're now measuring

21 head losses that in that view would be more

22 representative and more conservative than if we were

23 to leave it farther away from the screen.

24 CHAIRMAN WALLIS: But you're not going to

25 go back and redo the other tests with it on top of the

1 screen?

2 MR. BLEIGH: Well, some sensitivity tests

3 have shown it -- other than time it would not make

4 much difference.

5 MR. WILLIAMS: We have one plant series

6 themselves -- itself we did go back and retest for

7 other reasons, because of the reload changes and we

8 introduced the updated protocol in that test.

9 Okay. Ken?

10 MR. GREENWOOD: When we're doing our

11 testing we -- the intent was to try and include the

12 chemical precipitants in the test flume as one of the

13 particular debris. And prior to the issuance of the

14 WCAP we used the NUREG and ICET results to calculate

15 quantities of materials and the types of materials.

16 At that time -- and we'll talk a little

17 bit more about that later, but the surrogates were

18 selected from manufactured surrogates. They were not

19 produced as the WCAP suggests. And then later the

20 WCAP, once issued, was used to validate the

21 calculations, hand calculations if you will, that were

22 produced previously and showed that our quantities

23 were conservative.

24 MR. WILLIAMS: And conservative to the

25 point of, in many cases, if we factored into the WCAP

1 we would have quantities in there in excess of 15 to
2 20 times that of what -- well, actually from a
3 volumetric standpoint.
4 Now, we understand that we've got to look
5 at the differences in the characteristics of the
6 generated versus the manufactured, but in terms of
7 volume in many cases we were 15 to 20 times that of
8 what you would expect at the plant, just to be
9 conservative.
10 MR. GREENWOOD: So as I mentioned, we were
11 introducing these chemical byproducts into the
12 strainer test itself using these manufactured
13 materials. And the -- that's all the same
14 information. So the chemical precipitant was -- oh,
15 I'm sorry, I'm on the -- I'm ahead one.
16 And in an attempt to try and place the
17 chemical precipitants at the tail end of the
18 introduction, they were added last, just prior to
19 starting the recirculation sump.
20 So this kind of illustrates how we came up
21 with the chemical effects, and I think -- yes, I don't
22 think we need to go through --
23 MR. WILLIAMS: When you say "walk us
24 through the process here," we look at the WOG, the
25 ICET, and other industry data, and at the time, in

1 November -- October/November last year, we were
2 essentially utilizing mostly the ICET and other
3 industry data. Then, as we said, once we get the WOG
4 generator, then we're able to validate against that.
5 We then looked at plant-specific sump
6 parameters, and we selected an appropriate
7 manufactured material and basically it was sodium
8 aluminum silicate, but we were utilizing it from a
9 manufacturer standpoint, not from a generator
10 standpoint. In essence, both are somewhat surrogates,
11 but, you know, we were trying to use that to integrate
12 it into the overall head loss testing, as you can see
13 here.
14 So we do the flume testing with this
15 introduction of the debris, in addition to the
16 chemical constituents, measured the head loss that
17 qualifies the strainer, in cases -- we'll also talk
18 about that we collected downstream samples to get some
19 information about how the bypass -- what kind of
20 material bypassed and the characterization of that
21 material.
22 CHAIRMAN WALLIS: Well, it looks as if you
23 introduced these chemical precipitants before you
24 started the pump?
25 MR. GREENWOOD: That's correct.

1 MR. WILLIAMS: Yes, sir.

2 CHAIRMAN WALLIS: Because in the real
3 plant hasn't the pump been running for some time, and
4 these things are forming in the sump as a result of
5 chemical reaction?

6 MR. WILLIAMS: That's probably true. It
7 may be much later --

8 CHAIRMAN WALLIS: It may be some of the
9 last things that arrive. You've already built up your
10 bed. Then, the chemical precipitants come later, and
11 then simulate that.

12 MR. WILLIAMS: And what we were able to
13 see, though, you -- by -- when we layered the
14 materials, we put the chemicals in last, but we did do
15 it, as you said, prior to the pump.

16 CHAIRMAN WALLIS: Before you started the
17 pump. So you haven't built up the bed yet, so --

18 MR. WILLIAMS: Right. But you would get -
19 - because we are in a closed loop, you would recirc
20 that material through. One of our termination
21 criteria is we had to run through five full volume
22 turnovers, so there was -- once the debris bed started
23 forming there was plenty of opportunity for those
24 particulates to accumulate within the debris bed.

25 MR. BLEIGH: Again, you have a high

1 percentage of these particulates in these debris beds
2 recirculating. And so the concept that you have
3 particulates being added to the debris bed after it
4 swarmed actually took place on all these tests,
5 because of the recirculation of these particulates
6 once it passed the debris bed.
7 CHAIRMAN WALLIS: Well, the worst thing --
8 probably the worst thing is probably to have a fairly
9 thin debris bed, and then keep making chemicals until
10 you plug it up.
11 MR. BLEIGH: Again, it would probably
12 depend on what the form of that chemical --
13 CHAIRMAN WALLIS: It looks like the thin
14 bed of -- having a big, fluffy bed with the chemicals
15 spread through it isn't so bad. It's just like the
16 particulates.
17 MR. WILLIAMS: You have all kinds of --
18 that's right. It appears -- I mean, just like any
19 other particulate in a large fiber debris bed, you
20 have a lot of flow paths that as long as the --
21 CHAIRMAN WALLIS: All these people taking
22 out fiberglass insulation may be going the wrong way.
23 MR. BLEIGH: But there's no guarantee on
24 an actual accident condition to predict how much
25 fibrous debris will actually be generated and how much

1 actually transports to the screen, which is why we
2 continue to look at the entire range, you know, from
3 a thin bed of fibers all the way to the maximum fiber
4 condition postulated.
5 MR. GREENWOOD: Even for plants' predicted
6 high fiber loads, we would go back and look at the low
7 fiber conditions.
8 MR. WILLIAMS: Just information on the --
9 again, we were testing using tap water and doing --
10 the head loss results were adjusted based on dynamic
11 viscosities.
12 Just a quick word about some of the
13 surrogate materials we use. As I mentioned, the
14 inorganic zinc, which was giving us problems from the
15 EPA in the state we were testing, had a valuation to
16 use tin powder. From an epoxy standpoint, if we
17 weren't using chips in a low fiber condition, we would
18 simulate the epoxy powder using a walnut shell flour
19 arrangement.
20 Obsolete coating system -- as we had to
21 utilize current coating systems and we had coating
22 expert John Cavall and others evaluate, you know, the
23 relationship between those. And just for latent
24 debris we would use the SER recipe that was provided.
25 The chemical precipitants that were

1 utilized, the actual byproducts utilized or as shown -
2 - and these are coming from results from the ICET
3 test, and then subsequently confirmed by the WCAP.
4 These materials were -- we basically used the best
5 information we had available to come up with the
6 quantities of these materials and the type of these
7 materials.
8 Again, we did very plant-specific
9 evaluations, and this even varied to some degree. In
10 some cases, the plants themselves looked at the WCAP,
11 came up with a quantity, and gave us the quantity that
12 they wanted tested. In some cases, we did the
13 evaluation.
14 MR. CAIN: I'll take this one.
15 MR. WILLIAMS: Mr. Cain is going to talk
16 about penetration tests.
17 MR. CAIN: I'll just give you a quick
18 overview of our downstream sampling apparatus. Built
19 into the flume system downstream you'll see in our
20 next -- our next slide we have three isokinetic
21 sampling ports located in the six-inch diameter -- oh,
22 there it is -- conduit directly downstream of the
23 strainer. So the end of the flume is right here. The
24 strainer is immediately upstream of that. Our
25 sampling ports are downstream of that.

1 We have three independent ports, each
2 discharging from the pipe. We actually had a vertical
3 air over water manometer board that we used to set the
4 proper velocity head in the ports to ensure that the
5 velocity at the entrance to the ports was equal to
6 the --
7 CHAIRMAN WALLIS: That's how you sample
8 whatever gets through the screen, is that it?
9 MR. CAIN: That is correct, yes. And we
10 do it isokinetically, so that we know how much of a
11 volume we've taken off of the -- we've taken off of
12 the flow loop.
13 Here is the strainer. Okay. Downstream
14 of the strainer we have our pressure taps for head
15 loss. Downstream of that we have our isokinetic
16 sampling port. Now, the downstream piping is sized
17 such that the velocities in the downstream piping are
18 high enough to keep the material suspended and moving,
19 and to minimize preferential sorting of the material
20 based on size and density.
21 So we pull this off. We have our sampling
22 ports over here. We adjust the height of this. It's
23 a gravity-driven system. We adjust the height of this
24 to ensure that the velocities at the inlet ports are
25 equal to the velocities in the tube. And we collect

1 our sample over a given amount of time.

2 We take 10 -- we take samples every 10

3 minutes during the first hour of testing and every 20

4 minutes thereafter until reaching our termination

5 criteria. And then, those samples are analyzed by an

6 external laboratory.

7 MR. WILLIAMS: As Stu said, we take the

8 samples and we basically want to see a time history of

9 the material that is getting through. And as we

10 discussed with the staff yesterday, one of the things

11 that we -- there's a difference between taking the

12 samples and how you utilize the data. We were looking

13 for a couple of trends.

14 Do we get the K function even with a low

15 fiber condition? I mean, there was questions raised

16 as to, well, does an integrated test -- when you're

17 doing a head loss and a bypass test at the same time,

18 is one contradictory to the other? You can basically

19 argue it both ways.

20 I think if you get a higher differential

21 pressure, you will be forcing more material through,

22 whereas if you did a separate test and you had lower

23 amounts of material then you're getting another set of

24 results. I mean, what we did was take enough samples

25 on the high fiber conditions and to samples in lower

1 fiber conditions, and we're essentially looking for
2 trends.
3 I think from a particulate standpoint,
4 when you utilize the WCAP -- I mean, the assumptions
5 that are made that 100 percent of particulates gets
6 through, that's going to be consistent.
7 We were looking at hopefully being able to
8 utilize the data on the fibers themselves, where we
9 would get information from the SEM evaluation such as
10 this, where we actually -- based on sample size we had
11 the fiber lengths and the diameters of the fibers that
12 penetrated, characterized, and so that we can use that
13 data for looking into how much blockage you could
14 potentially get in the -- you know, going towards the
15 fuel assemblies themselves.
16 We were getting very consistent results
17 with some of the stuff that Enercon/Alion was pointing
18 out to typically the largest fiber we would -- length
19 we would get, though, is about 2,000 microns, all the
20 way down to 100 microns. So, in essence, it has
21 almost started to look more like particulates than the
22 fibrous material themselves.
23 But we did get a distribution of sizes,
24 and so that does give us some information. We also
25 saw a fairly loose correlation between the hole size

1 and the size of the material -- or fibers that would
2 get through -- the length of material -- excuse me,
3 the length of the fibers that would get through.
4 You would get more of the medium length
5 fibers with the smaller hole size than you would the
6 larger, so there was a somewhat loose correlation but
7 it was evident.
8 Last thing is termination -- one of the
9 last things, termination criteria. Very similar to
10 the BWRs -- and, again, we would use the increase in
11 the five-minute average is less than one percent and
12 head loss, and we had a calculated time based on the
13 flow rates of full -- five full volume turnovers of
14 the flume.
15 One of the things we also provide the
16 plants is information in order to do a data
17 extrapolation. What percent of change will you see in
18 that test termination, so that you can take a look at
19 that and see at what point -- in other words, if you
20 extrapolate that out, and what would you cut the pumps
21 back, and your NPSH margins become very large. And so
22 that gives you assurance that even with head loss
23 creep that you wouldn't exceed your NPSH allowable.
24 This just gives you an overview of the
25 data acquisition system that we utilized. We were --

1 this is flow rates. This is through the overhead
2 piping to the upstream piping. This is a head loss
3 curve that's being generated here. And what you see
4 in the blips here is when we were taking the bypass
5 samples, the isokinetic bypass sampling, showing
6 overall head loss here.
7 And then, we have a rate of change and a
8 five-minute average. This gives you flow rates down
9 here also, and this particular one was about 50 gpm in
10 this part of the test.
11 Jim Bleigh of PCI is going to walk us
12 through -- we thought it would be informative to see
13 some of the design drawings and some photos of the
14 existing replacement strainers. As we said, our
15 strainers are ranging from 800 square feet to over
16 7,000 square feet. I don't know if we -- if you added
17 up all of the strainer square footage existing, I
18 don't know if you'd reach 7,000 right now. But --
19 CHAIRMAN WALLIS: You're doing so well, I
20 don't think we need to take a break, do we? Just
21 continue to --
22 MR. WILLIAMS: No, I think we -- if we're
23 okay to do that. We're probably -- depending on the
24 questions, we're probably 10 minutes, 15 minutes from
25 finishing.

1 CHAIRMAN WALLIS: Okay. So you can go
2 away and bring your data after lunch.
3 (Laughter.)
4 MR. WILLIAMS: Okay. All right. Jim?
5 MR. BLEIGH: Okay. This is an arrangement
6 of vertical Shurflo strainers on a suction plenum that
7 basically partially covers the current sump opening.
8 Obviously, the part of the sump opening that is not
9 covered with strainers is covered with cover plate to
10 create the suction plenum below.
11 CHAIRMAN WALLIS: You are filling up the
12 sump with strainers.
13 MR. BLEIGH: No, this is actually on floor
14 level. And actually, the plenum is above the floor
15 level.
16 CHAIRMAN WALLIS: Oh, okay, okay.
17 MR. BLEIGH: And so actually this is --
18 this particular client has a really high water level,
19 and so we're in submergence with lots of submergence,
20 and the sump pit is below. And this simply provides
21 the platform on which all of the modules can be
22 placed.
23 CHAIRMAN WALLIS: Okay.
24 MR. WILLIAMS: Yes. This was the kind of
25 plant everybody wanted to have. They had 12 feet of

1 NPSH margin, no fiber. There was a --

2 MR. BLEIGH: And the next two slides is

3 actually a picture in our factory of this arrangement,

4 so this is what it looks like assembled in our plant

5 prior to shipment.

6 MR. CARUSO: How do you decide whether to

7 stack the disks vertically or horizontally?

8 MR. WILLIAMS: It's just a matter of the

9 plant arrangement and the space provided by the client

10 in terms of how I put the most space of screens in the

11 space, an arrangement that they have provided.

12 MR. CARUSO: I was just thinking in a case

13 like this you could stack them either way. How did

14 you decide to do it this way?

15 MR. WILLIAMS: Well, this takes up less

16 floor space than going horizontal, more square

17 footage.

18 MR. BLEIGH: So the footprint is much

19 smaller this way than the other.

20 CHAIRMAN WALLIS: But the discharge pipe

21 just goes straight down?

22 MR. BLEIGH: Well, actually, it's just the

23 opening in the sump pit collects water out of the

24 suction plenum, and then the suction pipes are

25 actually down int he --

1 CHAIRMAN WALLIS: Well, it's full of
2 water. But there's a hole in the middle of these
3 things that --
4 MR. BLEIGH: Correct. That's right.
5 CHAIRMAN WALLIS: And you see the pipe
6 coming out of the bottom, which goes straight down to
7 the sump pit.
8 MR. WILLIAMS: Right in this plenum, and
9 then it comes into the sump pit.
10 MR. BLEIGH: This core tube here goes all
11 the way down and interfaces with this base plate.
12 This is all open here sitting on the floor. So once
13 the water gets into the plenum area it will go towards
14 the sump and then spill over the sump into the sump
15 pit, and then it will be sucked by the suction line
16 there.
17 CHAIRMAN WALLIS: There is a plenum area
18 there. There is an enclosed plenum.
19 MR. BLEIGH: Yes, all of this is a closed
20 plenum.
21 MR. WILLIAMS: That's correct.
22 MR. BLEIGH: Everything that that sits on
23 is a sealed plenum.
24 MR. WILLIAMS: But to answer your
25 question, in many cases the water level at the onset

1 of recirc demands whether or not, you know, it gives
2 you -- do you have this opportunity to stack like
3 this, or must you spread it out? And if you've only
4 got two feet of water level, in this case we probably
5 had five or six feet --
6 MR. BLEIGH: This is like 4,600 square
7 feet of screens.
8 MR. WILLIAMS: This gives you a picture
9 of --
10 MR. BLEIGH: From above what it looks
11 like.
12 MR. WILLIAMS: The big picture.
13 MR. BLEIGH: Okay. In the next
14 arrangement we have, again, a single sump arrangement
15 in a plant. There is no screen redundancy in the
16 sump, and so basically we have two trains connecting
17 to a sump cover. Each of these trains are the same
18 size, and they can draw water from either side into
19 the common sump and then to the -- through the ECCS.
20 This is a horizontal strainer.
21 MR. WILLIAMS: All right. This is the
22 other arrangement that you mentioned.
23 MR. BLEIGH: Right. And then, this is a
24 picture of this unit installed. This is the only unit
25 that has been installed of our product so far. So you

1 basically have the pit over here, and the suction
2 pipes coming out and connecting to the end of the
3 strainers here, and then following along the outer
4 wall.
5 This is another horizontal arrangement in
6 a different plant. We have actually floor mounts.
7 The suction lines came to floor level and ended there.
8 This plant currently had existing like 25 square feet
9 per train as its existing screens. And when they
10 install ours they will have approximately 1,800 square
11 feet on each train. So it's a significant improvement
12 in the surface area.
13 This train is moving this way along the
14 outer wall. There wasn't room here with block -- you
15 know, maintenance activities during outages, and so
16 we're piping it over to this area where the same
17 number of modules will exist.
18 MR. WILLIAMS: There's just no two of
19 these footprints that seem to be alike, unfortunately.
20 MR. BLEIGH: This is actually another
21 horizontal strainer that connects to a cover plate on
22 a sump pit. It's a single train. There's not two for
23 this particular client. I think there's 14 modules
24 that go in one direction. Again, this pipe will work
25 itself around and connect --

1 CHAIRMAN WALLIS: Now, that central pipe,
2 is that the same diameter all the way through?
3 MR. BLEIGH: In this case, yes.
4 CHAIRMAN WALLIS: It just has different
5 hole sizes.
6 MR. BLEIGH: Right. So the hole sizes
7 near the suction end are going to be very small, and
8 then as we move this way the holes get larger. So
9 that, you know, at least in clean water, you know,
10 we're drawing the same water on this end as this end.
11 That way when the debris is collecting to the screen
12 it's collecting at the lowest flow rate possible.
13 CHAIRMAN WALLIS: This is a just a
14 Bernoulli effect, is that what --
15 MR. WILLIAMS: Yes.
16 CHAIRMAN WALLIS: Okay.
17 MR. WILLIAMS: Absolutely.
18 MR. BLEIGH: This is not a terribly good
19 picture, but we've tried to give some idea -- this is
20 an existing screen in a plant, and this is the actual
21 plant I think that --
22 CHAIRMAN WALLIS: The existing screen.
23 That's about the size of a person, is it?
24 MR. BLEIGH: Yes. This is the existing
25 screen. And then, if you go to the next picture, this

1 is what's replacing those is this.

2 CHAIRMAN WALLIS: It's two orders of

3 magnitude bigger or something like that.

4 MR. WILLIAMS: It's probably closer to

5 ten.

6 MR. BLEIGH: It's quite a bit larger.

7 MR. WILLIAMS: Not ten orders of

8 magnitude, ten times.

9 CHAIRMAN WALLIS: Two orders of magnitude.

10 MR. WILLIAMS: Yes, ten times the size.

11 CHAIRMAN WALLIS: Sixty times as big or

12 something like that.

13 MR. WILLIAMS: Right. And we've gone

14 from, you know, less than 50 square feet to several

15 thousand.

16 CHAIRMAN WALLIS: It says on the last

17 page.

18 MR. BLEIGH: And this is what that

19 particular screen looks like assembled in our factory

20 before shipment.

21 MR. WILLIAMS: So, in summary, as I noted

22 before that this testing that we've done has evolved

23 over time based on some good input and interface with

24 the staff as well as the clients and our own

25 evaluation of the results based on the PWR -- BWR

1 precedent.

2 The strainers are ranging from 25 to 75

3 times the existing stainer area, so you can see

4 there's a significant amount of area that is being

5 added in. Downstream effects evaluation are ongoing,

6 and we're continuing dialogue with the staff on how

7 those -- that information is going to --

8 CHAIRMAN WALLIS: That's a pretty dramatic

9 change, isn't it?

10 MR. WILLIAMS: Absolutely.

11 MR. BLEIGH: Very, very dramatic.

12 MR. WILLIAMS: Absolutely. I was over in

13 engineering at Browns Ferry in the '90s when we

14 replaced the strainers. I had a total of 40 square

15 feet for four strainers. I had a common suction

16 header and had 40 square feet, and we ended up with

17 like, you know, 800 per intake per suction header.

18 CHAIRMAN WALLIS: EDF is doing about the

19 same thing, isn't it? They're developing the same --

20 MR. WILLIAMS: Yes.

21 MR. BLEIGH: I would think so, yes.

22 MR. WILLIAMS: They actually -- I don't

23 know the exact numbers, but I actually think they're

24 even -- they may be even a little bit larger.

25 And that's all we have.

1 CHAIRMAN WALLIS: Why did we allow so much
2 time for all of these presentations? Must have been
3 Ralph.
4 So we're now three hours ahead or
5 something? No, not quite. I guess -- and we're going
6 to have lunch, so we're going to be two hours ahead.
7 GE is all we've got left today?
8 PARTICIPANT: Right. That's all we've got
9 left.
10 MEMBER KRESS: Let's take a long lunch.
11 PARTICIPANT: Do you think anyone wants --
12 no, let's see, can we go --
13 CHAIRMAN WALLIS: We're not allowed to go
14 ahead, are we?
15 PARTICIPANT: No, we're not allowed to go
16 ahead.
17 CHAIRMAN WALLIS: Well, we could have sort
18 of a roundtable discussion. Now, tell us what really
19 happened or something.
20 PARTICIPANT: We could do that, yes.
21 CHAIRMAN WALLIS: I don't think that
22 that's --
23 PARTICIPANT: We could just discuss.
24 CHAIRMAN WALLIS: Yes. Everyone is going
25 to be here anyway.

1 MEMBER BONACA: I had a question on the
2 chemical effects. I mean, do you have any preliminary
3 results? We heard from the previous vendor that they
4 had trouble, they have plugging, and they are
5 attempting to address it through different approaches.
6 I mean, what about your experience with chemical
7 compounds?
8 MR. WILLIAMS: Well, as I said, we -- we
9 used the manufactured chemicals as an integrated part
10 of the test. One of the things we did note is that in
11 one or two of the tests where the chemical constituent
12 was a large part of the overall particulate we did get
13 some substantial increases in head loss.
14 We're meeting with our client base, and
15 basically outlining some of the open issues and
16 discussing some resolution paths right now. I think
17 one of the things we probably need to do as an
18 industry a little bit better now is get our heads
19 together and get everybody going in the same direction
20 on this particular issue.
21 It's not necessarily conducive to have
22 five different, you know, screen vendors trying to
23 solve this problem independently of each other.
24 That's -- I think that's probably or hopefully what
25 we'll be looking at going forward as we're working

1 together.

2 CHAIRMAN WALLIS: It's all a work in

3 progress. And the real -- the real proof is that what

4 you come up with at the end is justifiable.

5 MR. WILLIAMS: Yes, that's correct.

6 CHAIRMAN WALLIS: And in a way, it's not

7 appropriate for us to look at the difficulties you may

8 have now that you're going to resolve. So it's

9 appropriate just to look at the finished product,

10 unless there's some really big surprises. Did you

11 have any big surprises?

12 MR. WILLIAMS: Any big surprises?

13 CHAIRMAN WALLIS: Well, middle sized.

14 (Laughter.)

15 Interesting surprises.

16 MR. WILLIAMS: We had a couple of

17 configurations set up with specific debris mixes, flow

18 -- a combination of flow rates, debris mixes. It

19 seemed like critical amount of fibers that we -- we

20 got some head losses that we -- were a little bit

21 unsuspecting.

22 Now, what we did, Dr. Wallis, every time

23 we went into a test we would do a prediction on 6224,

24 and then say, okay, that's kind of the upper bound

25 target, and let's see where we land there. We had one

1 or two mixes that --

2 CHAIRMAN WALLIS: See, this is the thing

3 which has characterized previous work. We had this

4 6224 correlation, and then Los Alamos did some tests

5 and found out that under some conditions you tugged

6 along and suddenly there was a big increase. And

7 then, people in the northwest did some tests and they

8 found that putting things in different orders and some

9 conditions gave you very different results.

10 And then, ANL did some things, and I think

11 in almost every case there was something which might

12 not have been anticipated which happened. And so

13 that's really the concern here is that -- have you

14 done enough -- have you covered enough of the

15 territory to find out the places where unusual things

16 tend to occur?

17 MR. WILLIAMS: We feel like we've done a

18 huge suite of varying debris mixes, flow rates, debris

19 placement. I mean, as you saw from our chart, you

20 know, we've had a -- we've got a large variation in

21 which we can look at the data and say, "What does that

22 tell us?" And it does tell us a couple of things.

23 CHAIRMAN WALLIS: And if there's one

24 anomaly in a hundred tests, then maybe the probability

25 of that occurring in the plant, you might -- it would

be rather small.

MR. WILLIAMS: That's correct. That's correct.

CHAIRMAN WALLIS: Anyway, all this is going to happen downstream somewhere when the smart guys from NRC really look at the final design and validation.

Can we take a break, or do we need to revisit -- I'm just wondering if we're going to have any more questions for these folks in the afternoon. Maybe after lunch we'll have some more thoughts.

Okay. Can we take a break? Usually we take -- an hour and a half? Well, do you want to take a break until 1:30? Is everybody happy?

MR. BUTLER: Dr. Wallis?

CHAIRMAN WALLIS: Yes.

MR. BUTLER: The next presentation is GE. It's going to be a closed session.

CHAIRMAN WALLIS: Yes.

MR. BUTLER: If that's going to be the last session of the day, will there be a reconvene of the people who are not --

CHAIRMAN WALLIS: Should we let the people go?

MR. BUTLER: Yes, that's what I'm

1 wondering.

2 MEMBER KRESS: I think they can.

3 CHAIRMAN WALLIS: Okay. So is it okay if

4 we come back at 1:30, or are you saying that you want

5 to come back earlier?

6 CHAIRMAN WALLIS: If it's a closed

7 session, will we be coming back at all?

8 CHAIRMAN WALLIS: Well, that's -- do you

9 want to ask any more questions this afternoon of these

10 folks, or can they go now?

11 MEMBER MAYNARD: Well, I think they can go

12 now. Again, all this is work in progress. I've

13 really been interested in their approach, in their

14 capabilities, and what they're doing. I don't have

15 any additional questions on that, so I -- from my

16 perspective, they can go.

17 CHAIRMAN WALLIS: Okay. So --

18 MEMBER KRESS: I think so. You know, what

19 they're doing I think looks appropriate, and they're

20 covering the range. And I would just like to see what

21 the results are. And I don't -- you know, I can't ask

22 them any more until then.

23 CHAIRMAN WALLIS: Yes. Okay. So you

24 folks can leave, and thank you very much for being

25 here. And that also applies to --

1 PARTICIPANT: Anyone who is not going to
2 be here for the GE section.
3 CHAIRMAN WALLIS: That applies to NEI,
4 too? Are you going to be here for the GE section?
5 You'll be here for that.
6 Okay. So we're going to take a break
7 until 1:30, and we will hear about the GE work then.
8 (Whereupon, at 12:12 p.m., the
9 proceedings in the foregoing matter went
10 off the record for a lunch recess.)
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CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards Subcommittee on Thermal Hydraulics

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Katherine Sykora
Official Reporter
Neal R. Gross & Co., Inc.

Plant Activities Beyond Strainer Replacement

ACRS Meeting

August 23, 2006

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Director, Safety Focused Regulation
Nuclear Energy Institute
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Status of Industry Activities

- 69 PWR units in US
  - 69 plants will have larger strainers installed by end of 2007
- Planned presentations will provide an update on strainer design and testing activities
- Plant activities extend well beyond installation of larger strainers

NEI

Plant Specific Modifications

- Actions to address debris sources
  - Modification, reduction or replacement of problematic insulation materials
  - Modification, reduction or replacement of problematic coatings
  - Reduction in latent debris
  - Reduction in problematic materials
- Containment modifications beyond strainer installation
  - Modifications affecting debris transport (e.g., debris interceptors)
  - Modifications affecting flood-up level, equipment storage
  - Modifications to lower containment to accommodate large strainers
- Downstream Flowpath
  - Modifications to ECCS and Containment Spray flow pathways
  - Involves orifices, pumps, valves and nozzles
  - Significant testing and effort necessary to maintain ECCS flow balance
  - Changes in fuel bottom grid openings

NEI

Plant Specific Modifications

- Procedure modifications/Training
  - Changes to pump start/stop criteria
  - Monitoring of recirculation flow
  - Technical Specification changes
- Programmatic changes
  - FME
  - Coatings
  - Design specification changes to control use of material in containment
- Buffer Replacement
  - PWROG evaluation of buffer replacement alternatives
- Containment Spray Initiation Changes ("Water Management Initiative")

NEI

ECCS PWR Sump Screen Testing Information

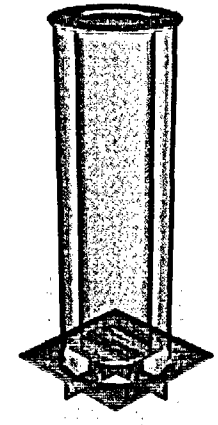
Prepared for ACRS
August 23, 2006

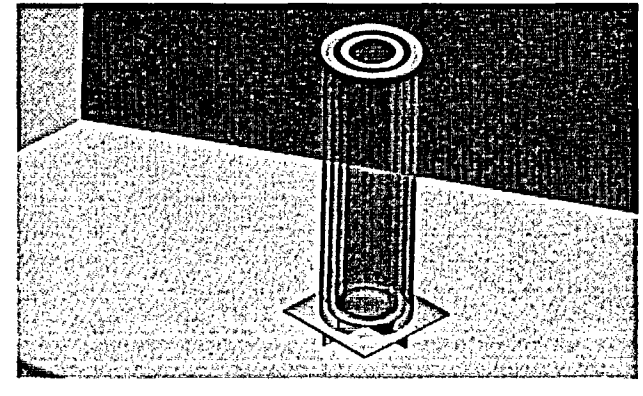
ENERCON

ALION
SCIENCE AND TECHNOLOGY

Outline of Information

- General Topics
  - Facility/Test description
  - Strainer design parameters
  - Licensees supported
- Specific Topics
  - Array Testing
  - Chemical Testing
  - By-Pass Testing





ENERCON

ALION
SCIENCE AND TECHNOLOGY

TPI

Facility/Test Description

- Dedicated GSI-191 Hydraulics and Chemical Effects Test Lab
- Located: Warrenville, IL
- 3000 sq. ft laboratory space for conducting experiments in debris transport, erosion, debris head loss, prototypical array and chemical effects testing
- Performing testing for 15 US and 2 foreign units

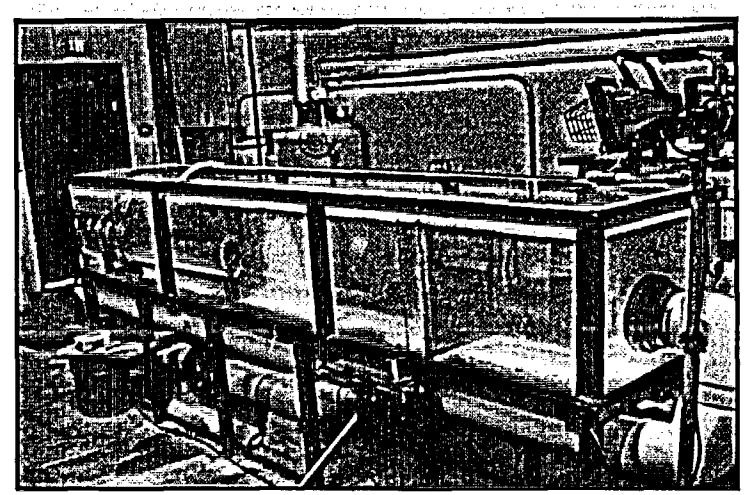
ENERCON

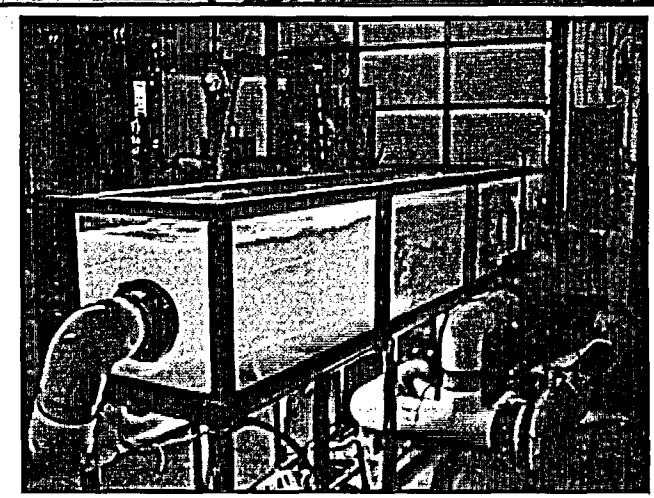
ALION SCIENCE AND TECHNOLOGY

TPI

Transport Testing

- Flume
  - 2' x 2' x 10' long
  - 250 gal
  - Bulk velocities up to 1.5 fps
  - 900 gpm centrifugal pump w/VFD
  - Ultrasonic Flow Meter
  - Thermocouples
  - Pressure Transmitters (L/M/H)
  - 5 micron filter for by-pass test
  - Instrumentation NAVLAP certified
- Single strainer testing
- Interceptor performance testing
- RMI transport testing
- Vortex testing





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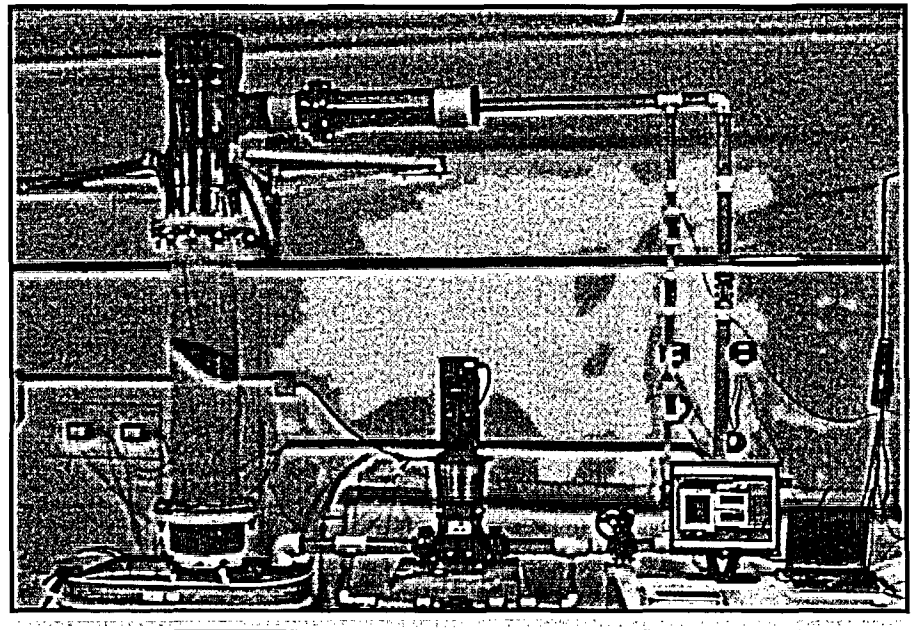
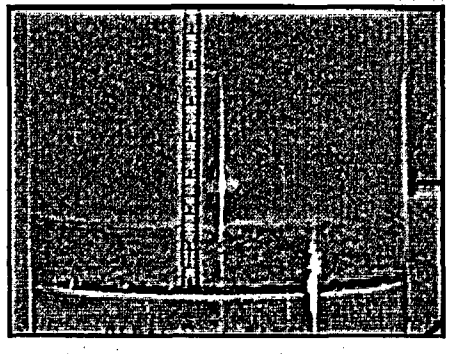
Material Head Loss Testing

- Vertical Test Loop
  - 12" diameter plate
  - 75 gal capacity
  - Approach velocities up to 0.5 fps
  - 200 gpm centrifugal pump w/VFD
  - 5 micron filter for by-pass test
  - Spray attachment
  - Ultrasonic Flow Meters
  - Turbine Flow Meters
  - Thermocouples
  - Pressure Transmitters
  - Instrumentation NAVLAP certified
- NUREG/CR-6224 validation
- Screen by-pass testing
- Spray erosion testing





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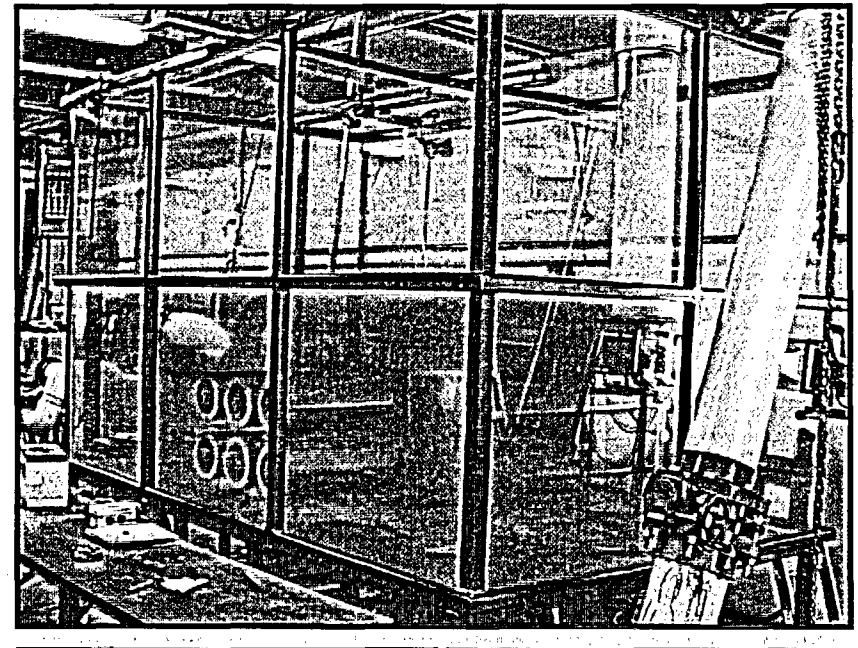
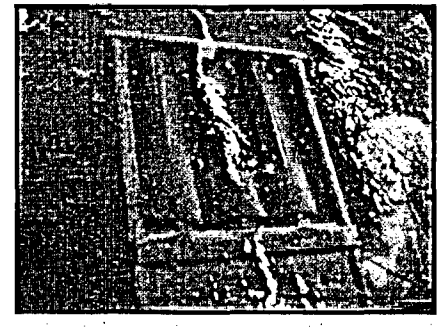
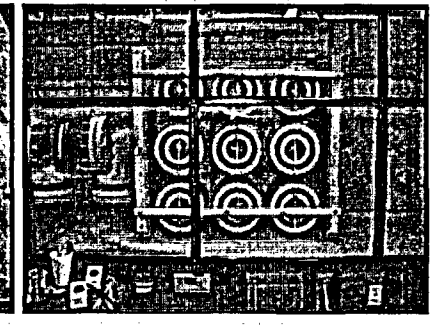
Prototype Tank Testing

- Test Tank
  - 6' x 8'x 10'
  - 3500 gal
  - 2500 gpm centrifugal pump w/VFD
  - 5 micron filter for by-pass test
  - Heating and Cooling Control
  - Constant Turbidity Measurement
  - Ultrasonic Flow Meters
  - Thermocouples
  - Pressure Transmitters (L/M/H)
  - Turbine Agitator
  - Instrumentation NAVLAP certified







- Full scale prototype testing
- Screen by-pass testing

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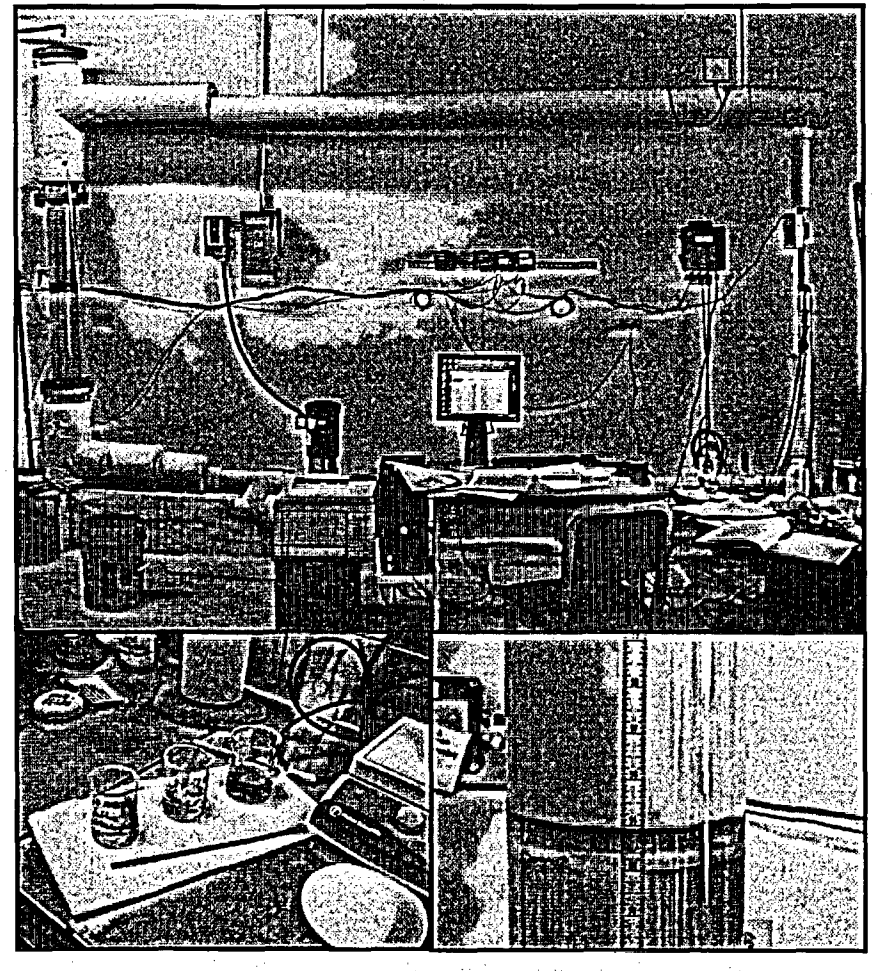
Chemical Effects Head Loss Testing

- Vertical Test Loop
  - 6" diameter plate
  - 16 gal capacity
  - Approach velocities up to 0.6 fps
  - 55 gpm centrifugal pump
  - Heating/Cooling (T_{max} = 160 deg F)
  - Ultrasonic Flow Meter
  - Thermocouples
  - Pressure transmitters
  - pH transmitter
  - Instrumentation NAVLAP certified
- Flat plate head loss testing for impact of chemical effects
- DI/RO water environment
- Sump chemistry environment



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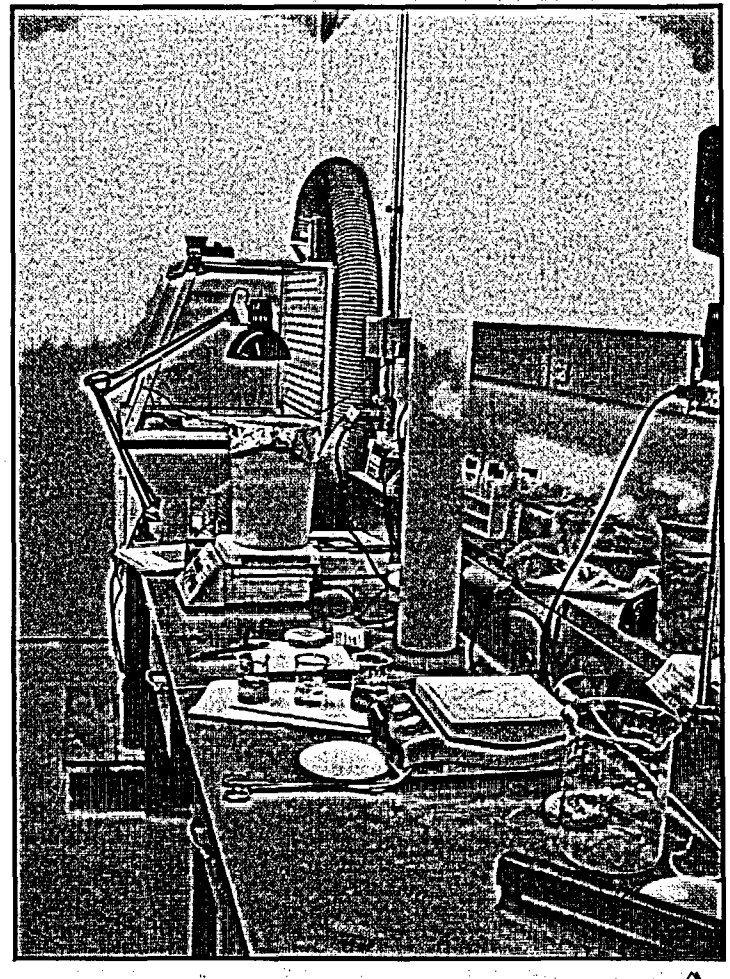
Bench Testing

- Scanning Electron Microscopy (SEM) – Appendix B
- Particle density measurements
- Size distribution for particulates
- Bed density measurements
- Inductively Coupled Plasma (ICP)
- Dissolution testing under various pH
- Settling velocity of materials
- WCAP particulate generation
- Surrogate validation



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Replacement Strainer Design Parameters

Plant	Approximate Screen Size (ft^2)	Approx. Flow Rate (gpm)	Screen Approach Velocity (ft/sec)	Perforated Plate Hole Diameter (inch)	NPSH Margin (ft of H_2O)	Buffering Agent
Duke – Catawba Units 1 and 2	2,200	16,000	0.016	3/32	7	Sodium Tetra borate
Duke – McGuire Units 1 and 2	2,000	16,000	0.016	3/32	12	Sodium Tetra borate
Progress – Crystal River 3	1,100	8,500	0.017	1/8	1	Trisodium Phosphate
Progress – Harris	3,000 per sump Two Sumps	6,400	0.005	3/32	3.1	Sodium Hydroxide
Progress - Robinson	4,200	3,800	0.002	3/32	5.5	Sodium Hydroxide
Exelon – TMI	2700	8700	0.007	3/32	1.3	Sodium Hydroxide
First Energy – Beaver Valley Unit 1	2,800	14,500	0.012	3/32	4.6	Sodium Hydroxide
First Energy – Beaver Valley Unit 2	3,400	13,000	0.009	3/32	1.6	Sodium Hydroxide
First Energy – Davis Besse	1,200	11,000	0.020	3/16	1.5	Trisodium Phosphate
Entergy – Indian Point Unit 2	3,150 – IR Sump	7,100	0.005	3/32	1	Trisodium Phosphate
	1,180 –VC Sump	3,500	0.007	3/32	8	
Entergy – Indian Point Unit 3	3,150 – IR Sump	5,300	0.004	3/32	0.6	Sodium Hydroxide
	1,000 –VC Sump	4,100	0.008	3/32	7.6	
Edison – San Onofre Units 2 and 3	990 per sump Two Sumps	3,500	0.008	3/32	4	Trisodium Phosphate

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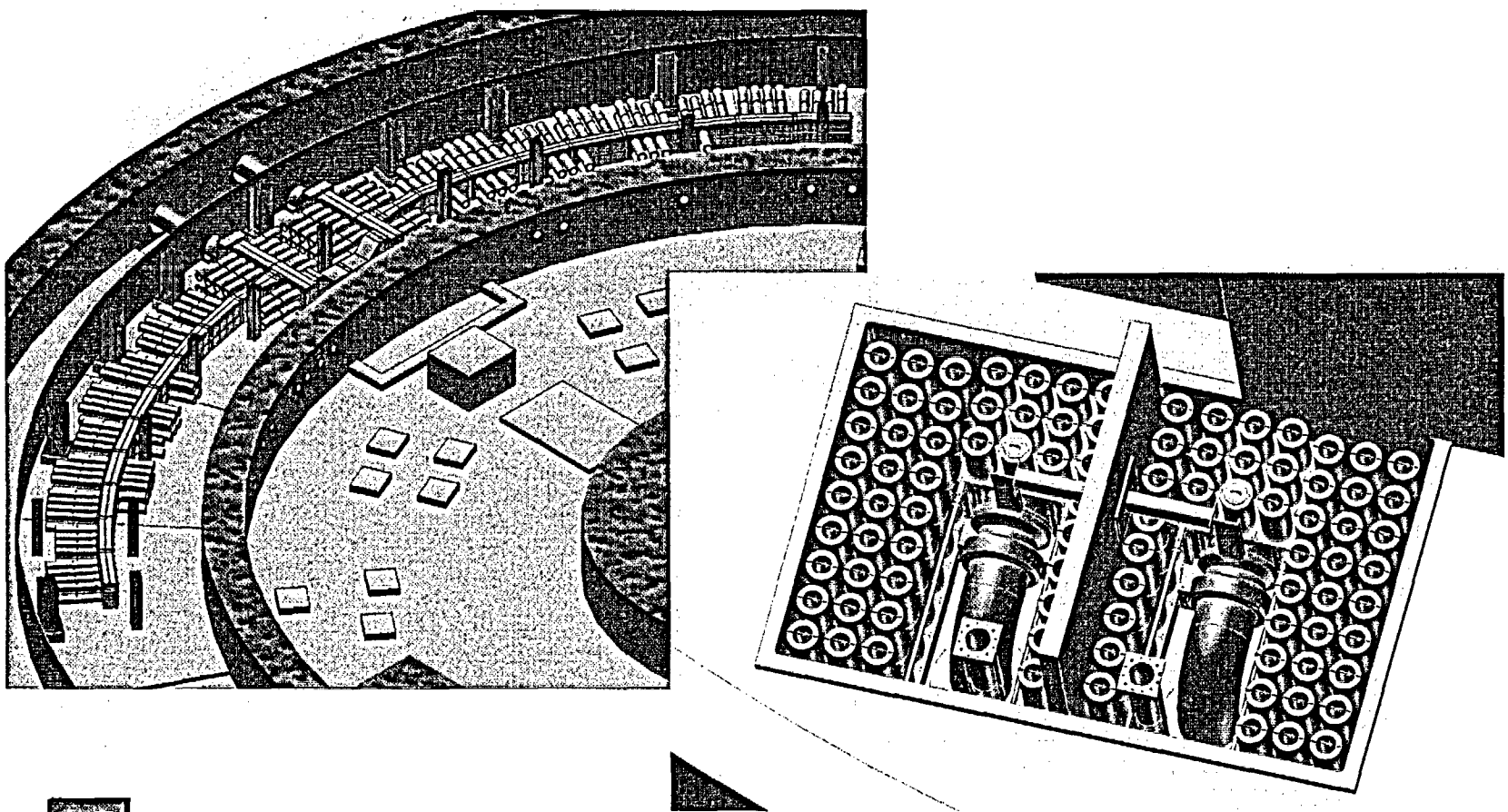
Replacement Strainer Designs



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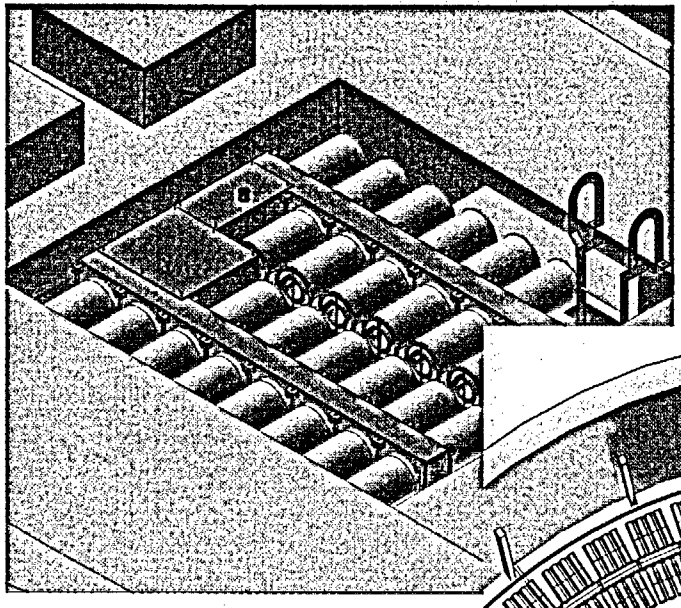
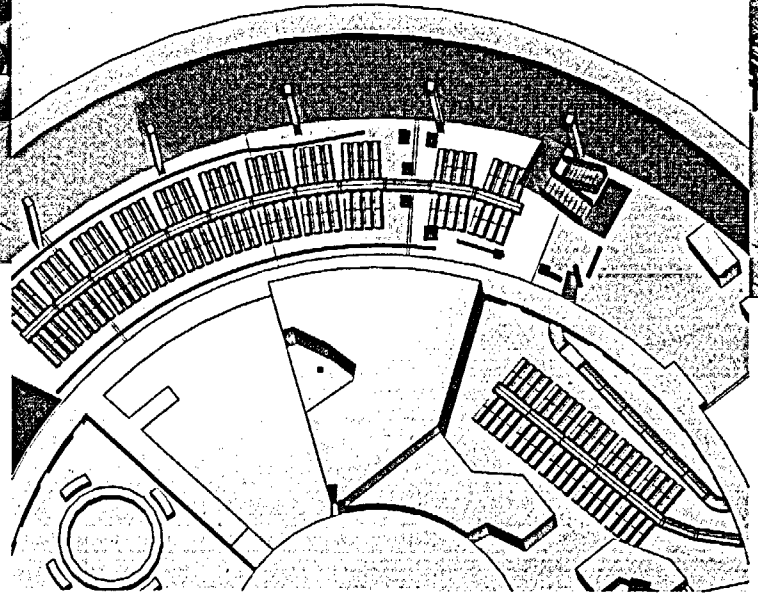
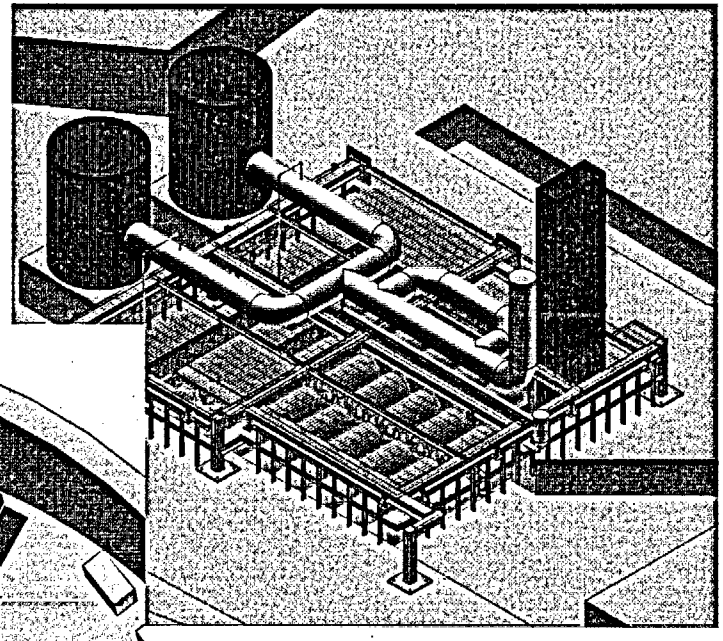
Replacement Strainer Designs







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Status of Testing

Plant	Prototype Debris Testing	Chemical Effects Testing
Duke – Catawba Units 1 and 2	Completed	Completed
Duke – McGuire Units 1 and 2	Completed	Completed
Progress – Crystal River 3	N/R	TBD
Progress – Harris	TBD	TBD
Progress - Robinson	Completed	Scheduled
Exelon – Three Mile Island	Scheduled	Scheduled
First Energy – Beaver Valley Unit 1	In process	Scheduled
First Energy – Beaver Valley Unit 2	Scheduled	Scheduled
First Energy – Davis Besse	N/R	TBD
Entergy – Indian Point Unit 2 & 3	Completed	Scheduled
Edison – San Onofre Units 2 and 3	Completed	Completed
Entergy – Waterford 3 *	N/A	Scheduled
FPL – St. Lucie Units 1 and 2 *	N/A	Scheduled
FPL – Turkey Point Units 3 & 4*	N/A	Scheduled
FPL – Seabrook*	N/A	Scheduled

* Alion only performing chemical effects testing

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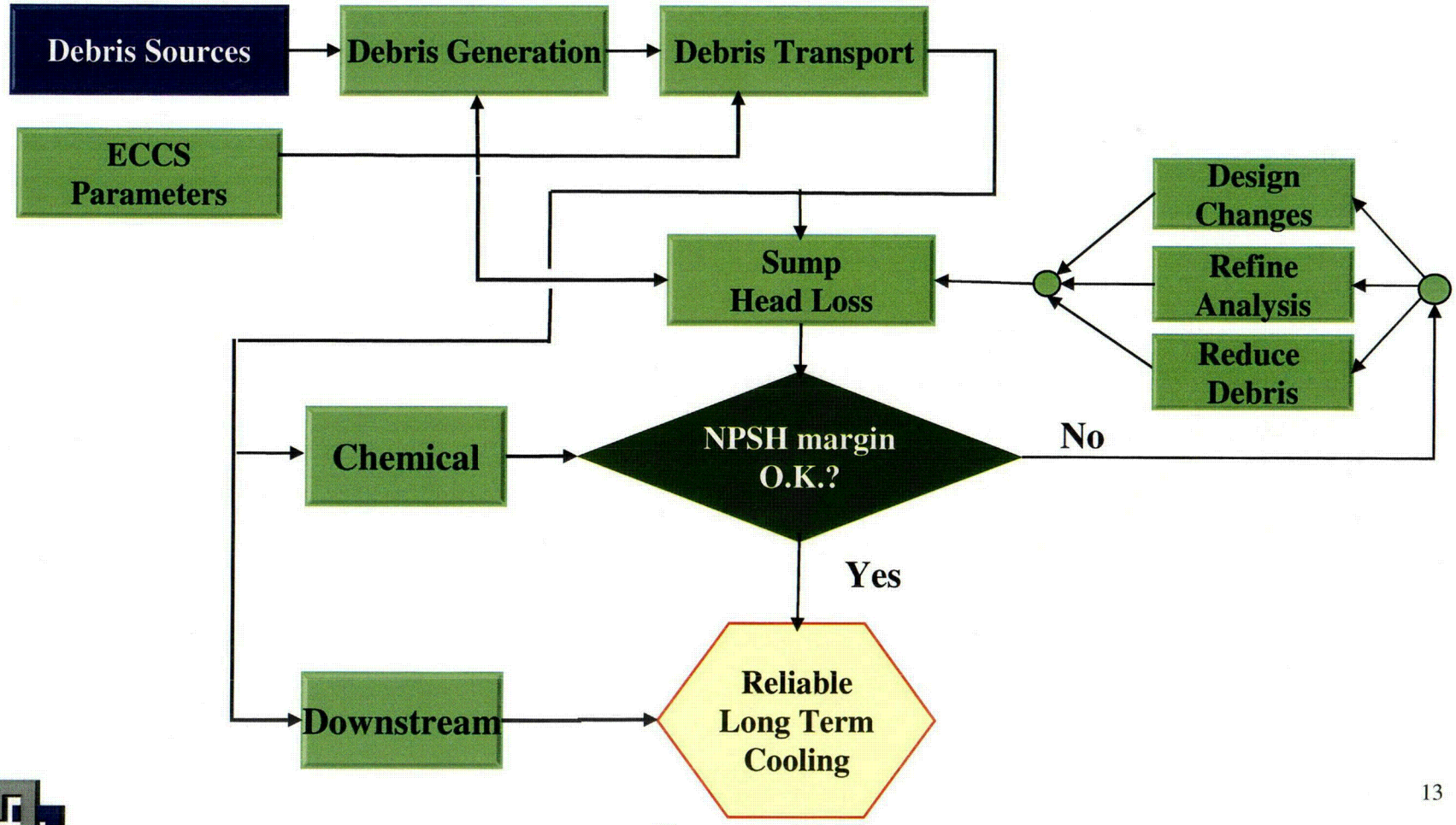
Major Steps in Assuring Reliable Long Term Cooling



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Array Testing

Testing Considerations

- **Scaling and Selection of Prototype**
  - Full scale section of replacement screen tested
  - Full size top-hats used in all testing
  - Sides on array to simulate boundary conditions
  - Tank turbulence/hydraulics are part of pre-test
  - Ensure "no settling" of debris
  - Water levels are consistent with containment level cover
  - Approach velocities are average approach velocities (Q/A) consistent with full scale section – no scaling of velocity

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Array Testing (cont.)

Testing Considerations (cont.)

Two Part Array testing:

- **Low fiber regime**: all particulate material introduced into tank and stirred. Fiber batched in quantities equivalent to 1/8" thick beds up to 1" thick

- **High fiber regime**: fiber + particulate batched in quantities with constant mass/particulate ratio to provide homogenous debris bed buildup up to maximum load.

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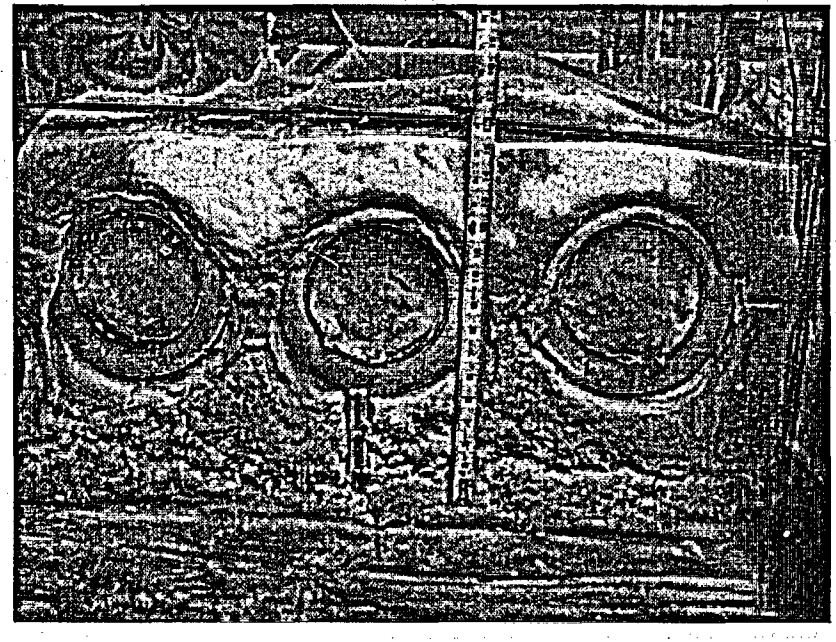
Array Testing (cont.)

Modular Strainer Setup

Full scale section of prototype



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Array Testing (cont.)

Debris Preparation Methodology

- The debris quantities are based on the transport of "fines" or "small" as per NEI-04-07.
- The debris characteristics used in testing comport with the sizing of "fines" or "small" as per NEI-04-07.
- Latent dirt/dust debris in accordance with SER Appendix VII recipe.

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Array Testing (cont.)

Debris Preparation Methodology (cont.)

Fiber:

- All fiber is boiled for 15 minutes.
- Fiber is then placed in a bucket with water and stirred with a power stirrer until there are no large clumps left. Fiber spans the range of NUREG/CR-6224 sizes 1 through 4.
- Fiber introduced in small batches released a few inches under the surface of the tank.

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Array Testing (cont.)

Debris Preparation Methodology (cont.)

Particulate:

- Particulate is placed in a 5 gallon bucket with water and stirred with a paint stirrer for at least 10 minutes.
- Bucket examined to ensure no "clumps" of particulate and that all particulate have been placed in solution.
- Particulate laden water introduced in small batches released a few inches under the surface of the tank.

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Array Testing (cont.)

Debris Introduction Methodology

- Debris mixed based on test plan
- Fiber alone, particulate alone, or
- Combined fiber+particulate batch
- Debris introduced depending on actual screen layout
- On-grade installation vs. Sump pit
- Debris introduced at discharge into tank to ensure thorough mixing
- Tank hydraulics ensure material is in suspension but not disturbed on the array.
- **No "near-field" effect or settling of debris**
- Debris accumulates on screen based on approach velocity

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Array Testing (cont.)

Array Test Conduct/Termination Criteria

- Array testing may start with a flow sweep to establish the clean strainer head loss.
- The lowest flow is established and steady state is ensured.
- The first debris addition is added slowly to ensure dispersal.
- Once debris addition is terminated the countdown begins for 5 pool turnovers.
- After 5 pool turnovers, the criteria for the next debris batch addition or test termination is an increase in head loss < 1% in 10 minutes.
- Optional: Flow increase at the end of the test
- Optional: Decrease water level for vortex investigation

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Array Testing (cont.)

Key Observations to Date

- Tendency of material to settle without agitation
- Pool hydraulics relatively easy to maintain
- Particulate surrogate inhibits good visualization
- Debris introduction and preparation can affect results
- Geometry effects can be pronounced:
  - Array orientation
  - Spacing between adjacent screen assemblies
  - Wall, floor, structural boundaries
  - Debris settling within pits

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Array Testing (cont.)

Key Observations to Date (cont.)

- High fiber load tests will partially fill the interstitial volumes.
- Interstial volume calculations result in very conservative head loss calculations.
- High fiber load test data used develop geometry factor.
- NUREG/CR-6224 head loss correlation used to extrapolate the test data to develop parametrics of particulates.
- Use of full size modules and plenums allow direct extrapolation of test data to plant array design.

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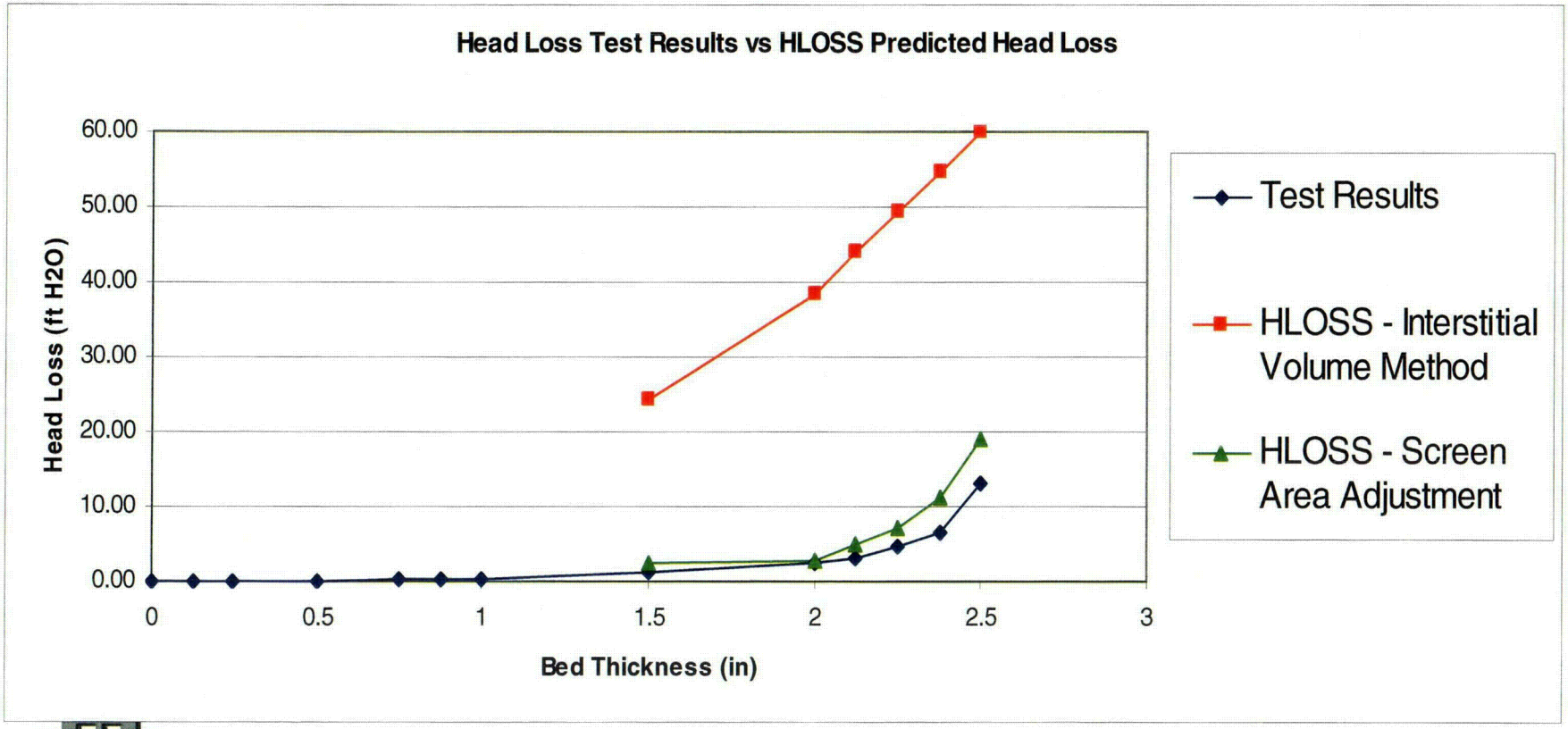
Array Testing (cont.)



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Array Testing (cont.)

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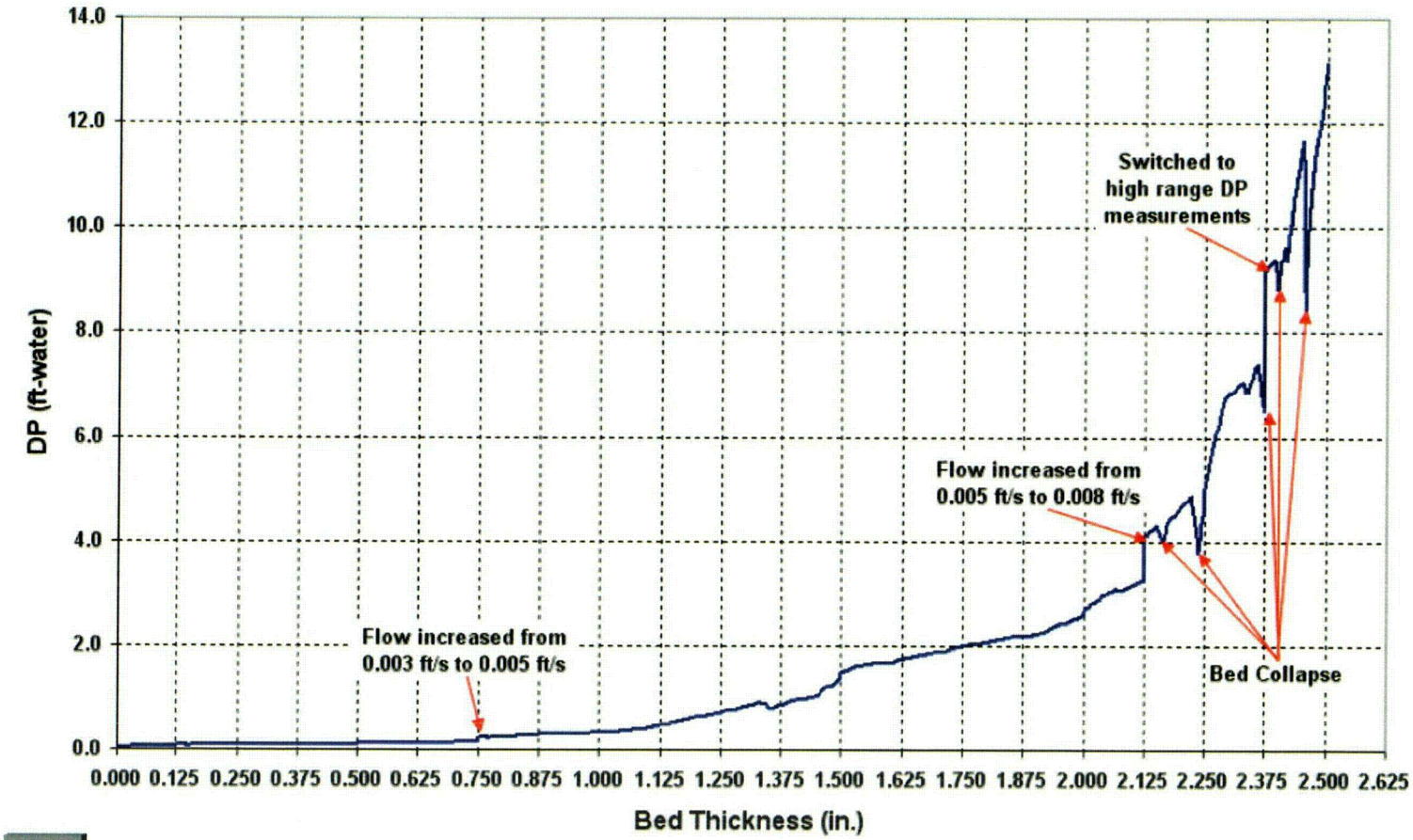
Array Testing (cont.)



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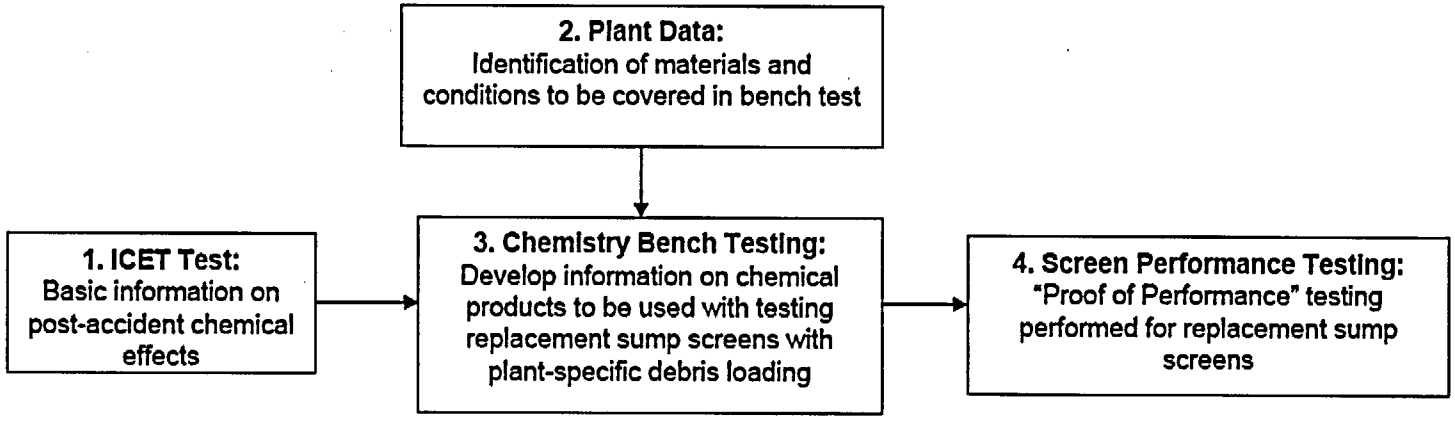
Head Loss due to Chemical Effects

- Based on PWROG WCAP Approach
- WCAP "Chemical Precipitate" Generation Report
- Screen Head Loss Testing



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Head Loss due to Chemical Effects (cont.)

- Approach based on bump-up factor to existing large scale array test results
- Utilize vertical test loop (flat plate) to determine head loss impact associated with chemical effects (precipitants and fluid effects)
- Plant specific data (pH, temperature, debris type and quantities)
- Precipitants based on WCAP Methodology
- Vertical loop tests are run to determine the impact each constituent has on head loss
- Scaled debris loads (type and bed thickness) are used from the full scale test to ensure consistency between two data sets

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Chemical Model

- Quantity and type of chemical precipitants determined from WCAP and plant specific inputs
- Debris quantities scaled to vertical loop screen area – approach velocities consistent with full screen
- Chemical precipitants are developed from the WCAP chemical particulate generator (no surrogates) and settling rates validated

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Head Loss Testing - Chemical

- Head loss impact due to precipitants and fluid chemistry investigated both separately and integrated in the vertical loop
- Investigating layered versus mixed precipitant debris beds
- Testing in both sump chemistry and DI or RO water
- Steady state and time dependent debris addition

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Fiber Debris Bypass Testing

- Specific Fibrous Debris Bypass Testing
- Factors which contribute to debris bypass
  - Clean strainer surface area
  - Total strainer surface area
  - Average approach velocity
  - Perforated plate hole size
  - Differential pressure across the fibrous debris bed

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Fiber Debris Bypass Testing (cont.)

- Specific Fibrous Debris Bypass Testing
  - This test is not a debris head loss test
  - Fiberglass insulation debris prepared the same as used in head loss testing – no particulate
  - All down stream flow is passed through 5 micron bag filters.
  - Prepared fiber is introduce in small batches and allowed to accumulate on the strainer before next batch is added.
  - Fiber is added in small batches to eventually fully cover the strainer.
  - Flow rate is increased to increase head loss across fiber bed to the simulate the predicted fiber and particulate debris head loss.

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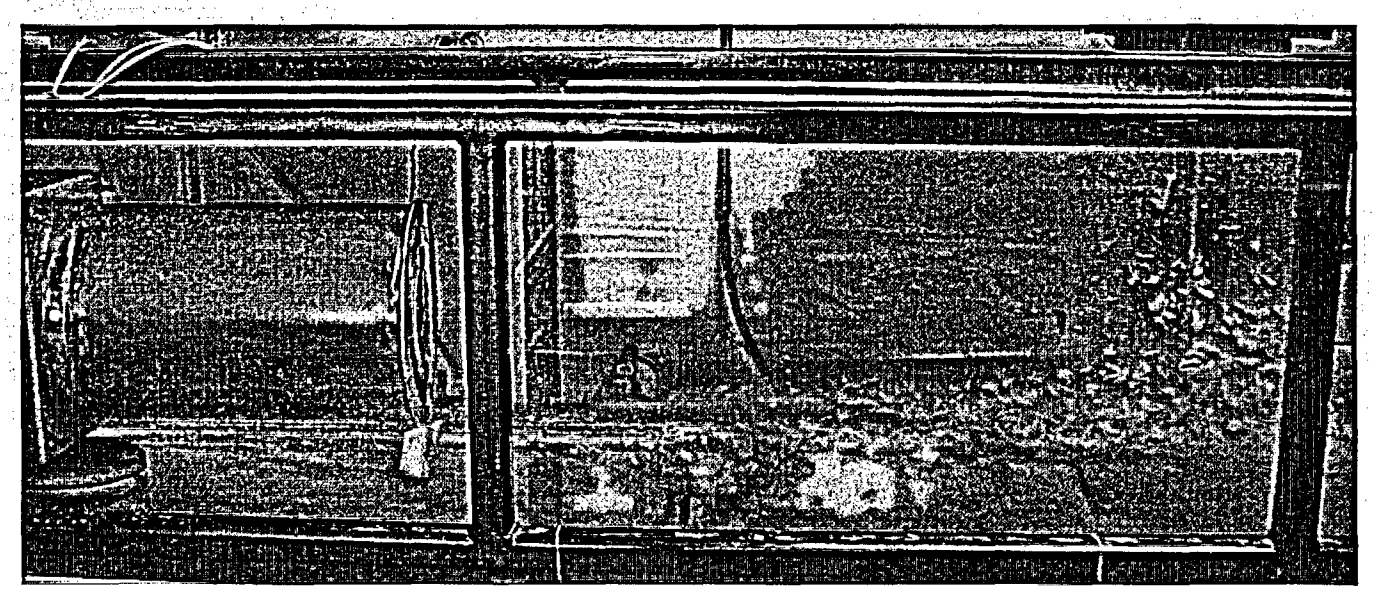
Fiber Debris Bypass Testing (cont.)



Fibrous Debris Traveling to the Top-Hat Strainer

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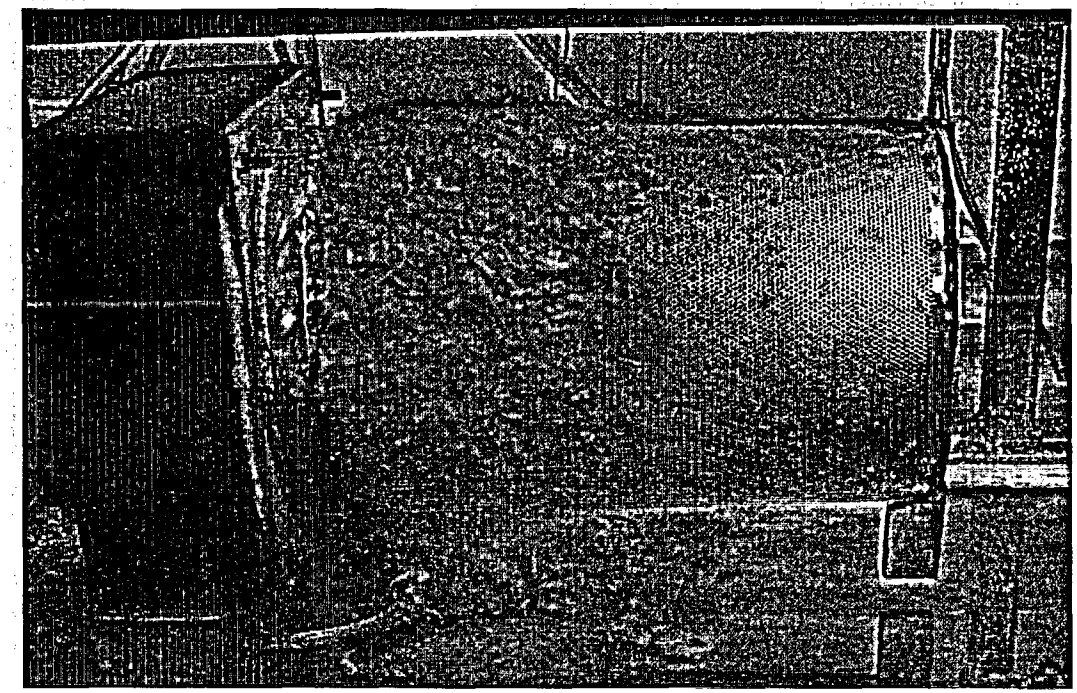
Fiber Debris Bypass Testing (cont.)



Half- inch Equivalent Fibrous Debris Loading

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Fiber Debris Bypass Testing (cont.)

- Fiber Bypass testing observations:
  - Most fiber bypass occurs when fiber debris first starts depositing on strainer surface
  - The fiber bypass becomes essentially zero once a fiber bed is formed over all the strainer surfaces
  - Quantity of bypass fiber proportional to
    - strainer area
    - approach velocity
  - Quantity of fiber bypass is significant

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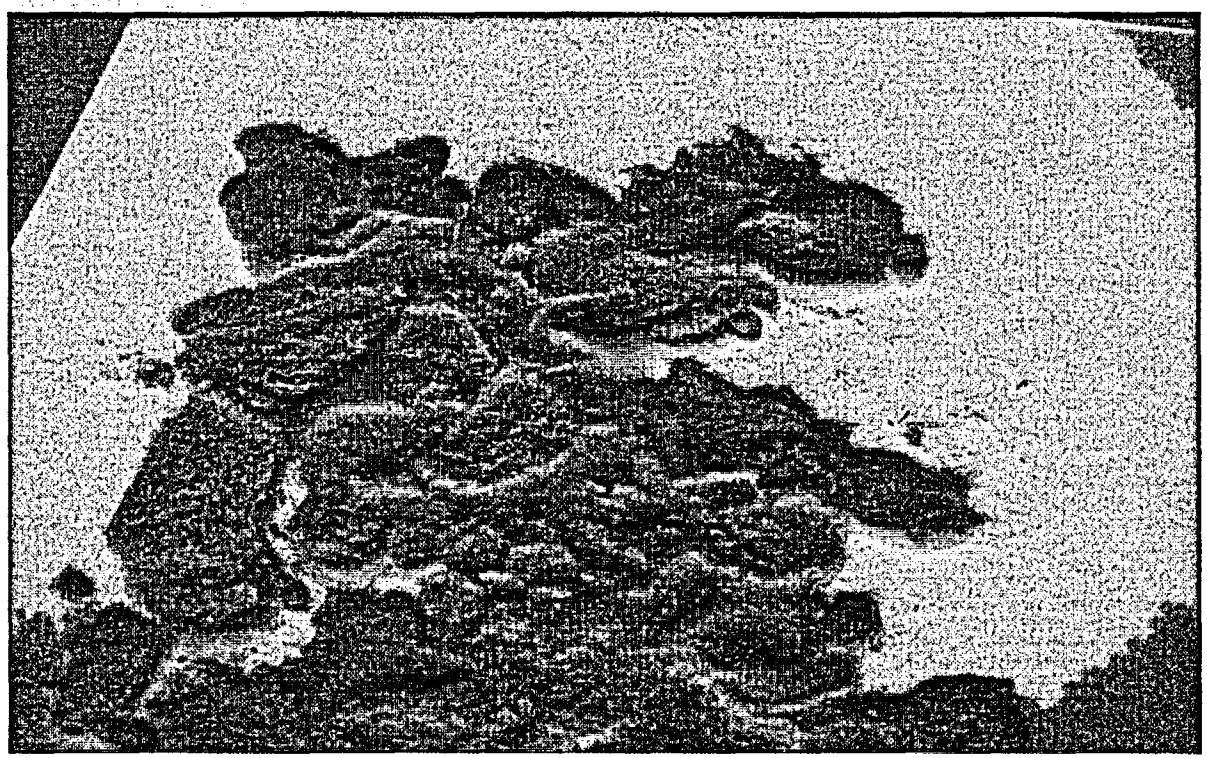
Fiber Debris Bypass Testing (cont.)

Fiber Collected Downstream of a Perforated Plate Strainer



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Fiber Debris Bypass Testing (cont.)

Enercon's Debris Bypass Eliminator *

- Knitted Wire Mesh Construction
- Inserted within the walls of Strainer Modules
- Porous media (approximately 98% porosity) that reduces the quantity and size of fibers bypassing perforated plate
- Minimal increase in clean strainer head loss due to the high porosity of wire mesh material

***Patent Pending**

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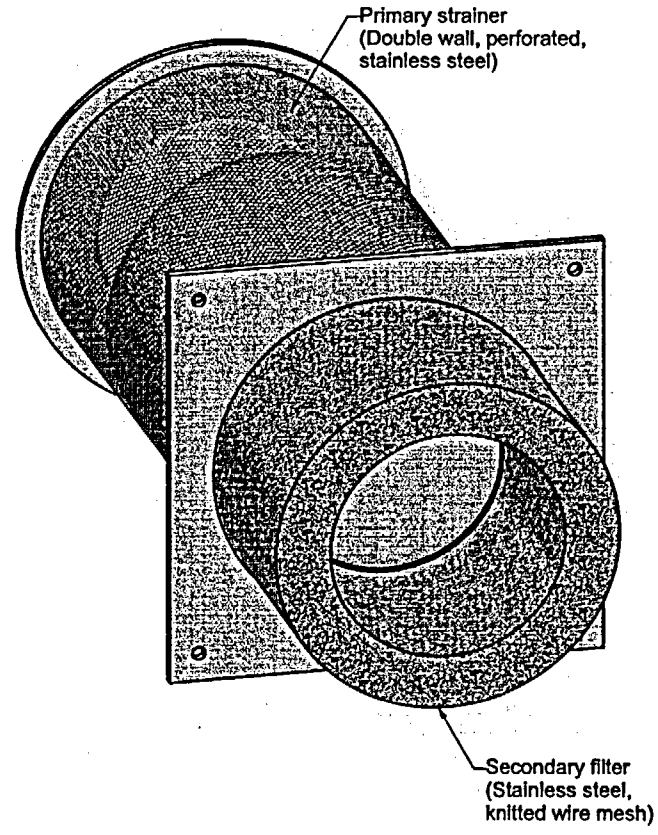
Fiber Debris Bypass Testing (cont.)

Enercon's

Debris Bypass Eliminator



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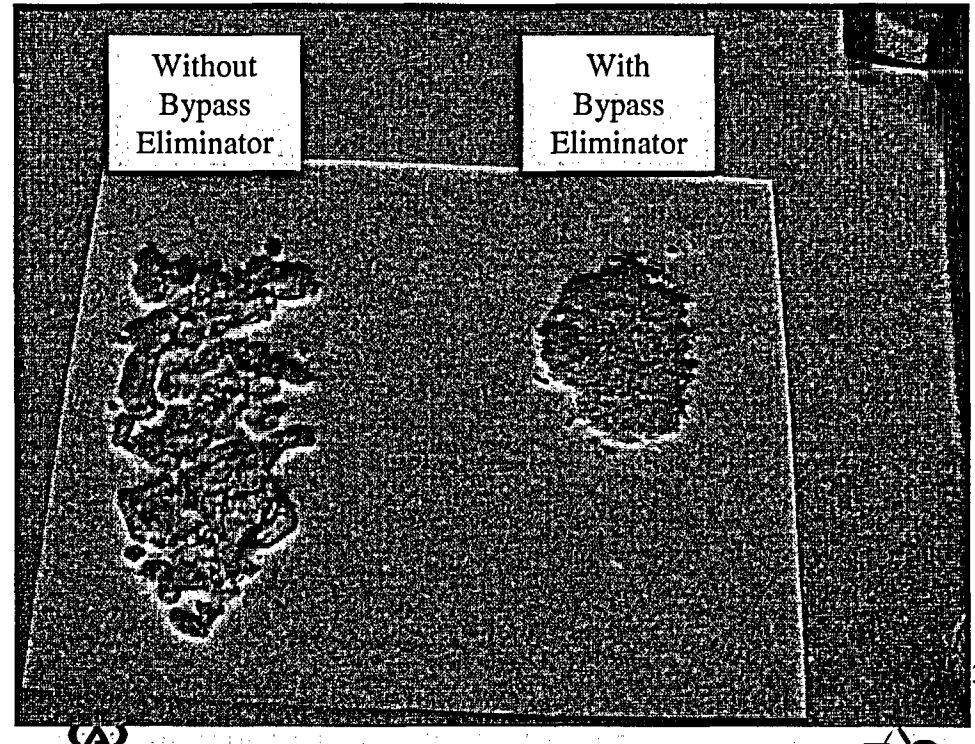
Fiber Debris Bypass Testing (cont.)

- **Fiber Debris Bypass Testing**
  - Significant reduction in the quantity of fiber bypass when the knitted wire mesh bypass eliminators were inserted into the strainer top hat modules



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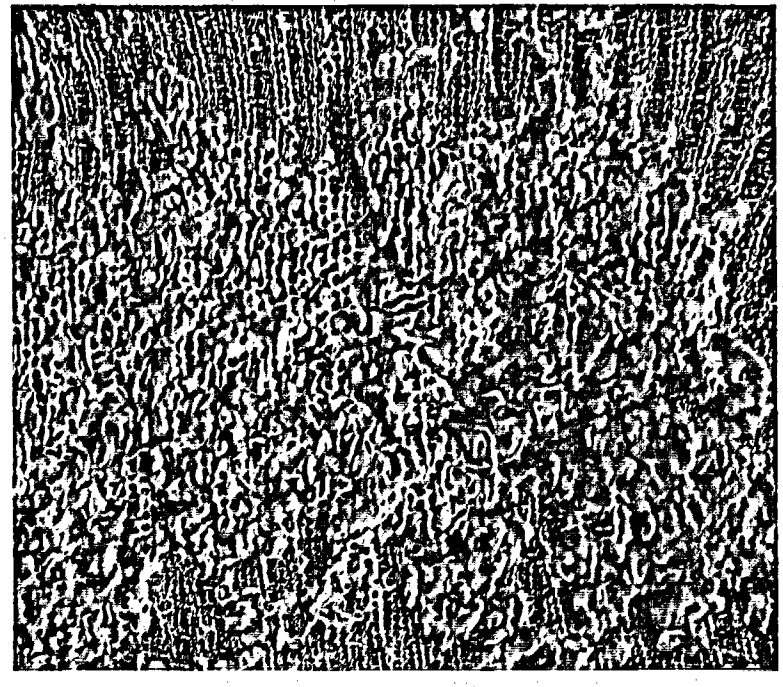
Fiber Debris Bypass Testing (cont.)

Debris Bypass Eliminator

Testing indicates that the fibers penetrating the strainer perforated plate openings exhibit a trapping effect on the surface of the wire mesh material



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Fiber Debris Bypass Testing (cont.)

Microscopic Examination of Fiber Bypass Length

- **Without the bypass eliminator**
  - Fibers at the edge of fiber balls ranged from 1000 - 3000 microns in length
  - Shorter fibers were observed inside the balls of fiber
  - Displayed fiber characteristics - clumping and bridging properties
- **With the bypass eliminator**
  - Eighty to ninety percent of fibers were shorter than 500 microns
  - Nearly all fibers were shorter than 1000 microns
  - Displayed particulate characteristics - dust like properties

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Solving Flow Problems Since 1894

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ACRS T-H Phenomena Subcommittee GSI-191 Issues Meeting

Rockville, MD
August 23-24, 2006

AREVA

The information contained in this presentation is provided to increase the knowledge of the NRC/ACRS with regards to our strainer performance testing for GSI-191.

This information is not submitted on behalf of our clients, nor is it intended to replace information provided to the NRC directly by the licensees.

All specific requests regarding this information need to be directed toward the licensees.

AGENDA

> General Topics

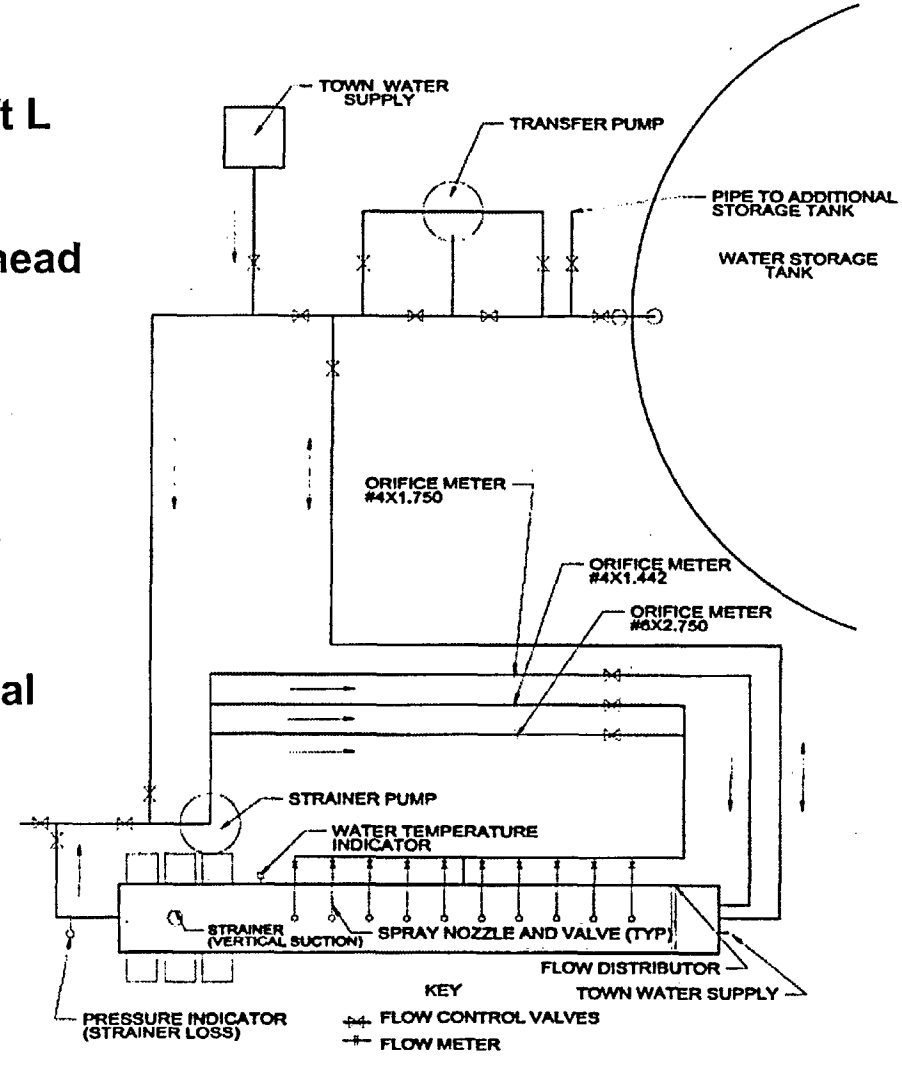
- Facilities Overview
- Overview of Licensees & Strainer Design Parameters

> Specific Topics

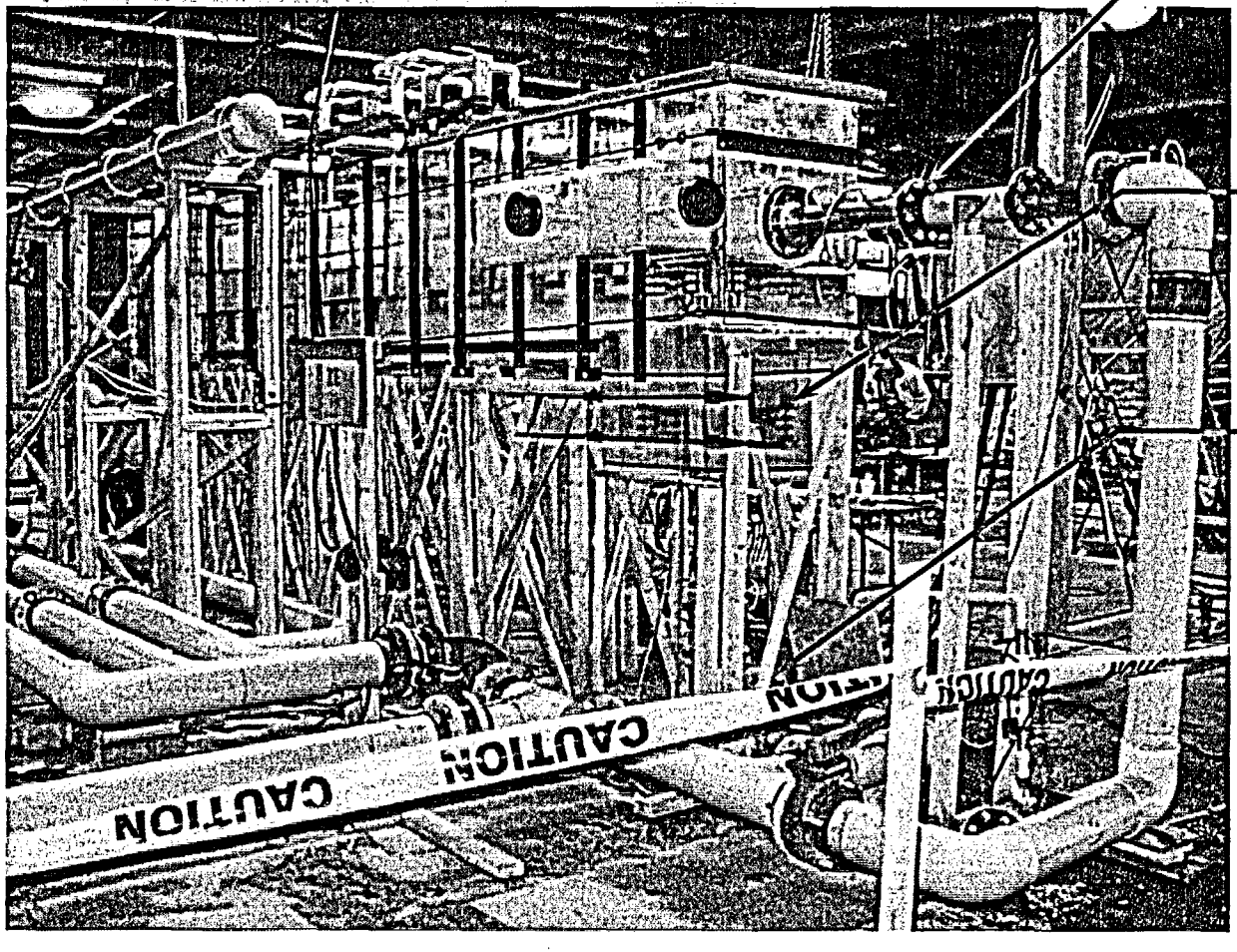
- Scaling Methodology
- Debris Preparation Methodology
- Debris Introduction Methodology
- Head Loss Due to Chemical Effects
- Screen Penetration Testing
- Termination Criteria

> Facilities Overview

- Flume Dimensions:
  2.25 ft W x 3.25 ft D x 20.9 ft L
- Calibrated Flow Capacity:
  10 – 120 gpm @ max 30 ft head
- Return flow through 10 overhead nozzles or to upstream end of flume
- Spray nozzle manifold flow range: 10 gpm to 200 gpm
- Strainer pressure differential range: 0.02 ft to 12 ft
- Water temperature range recorded during tests:
  40°F – 70°F



> Facilities Overview



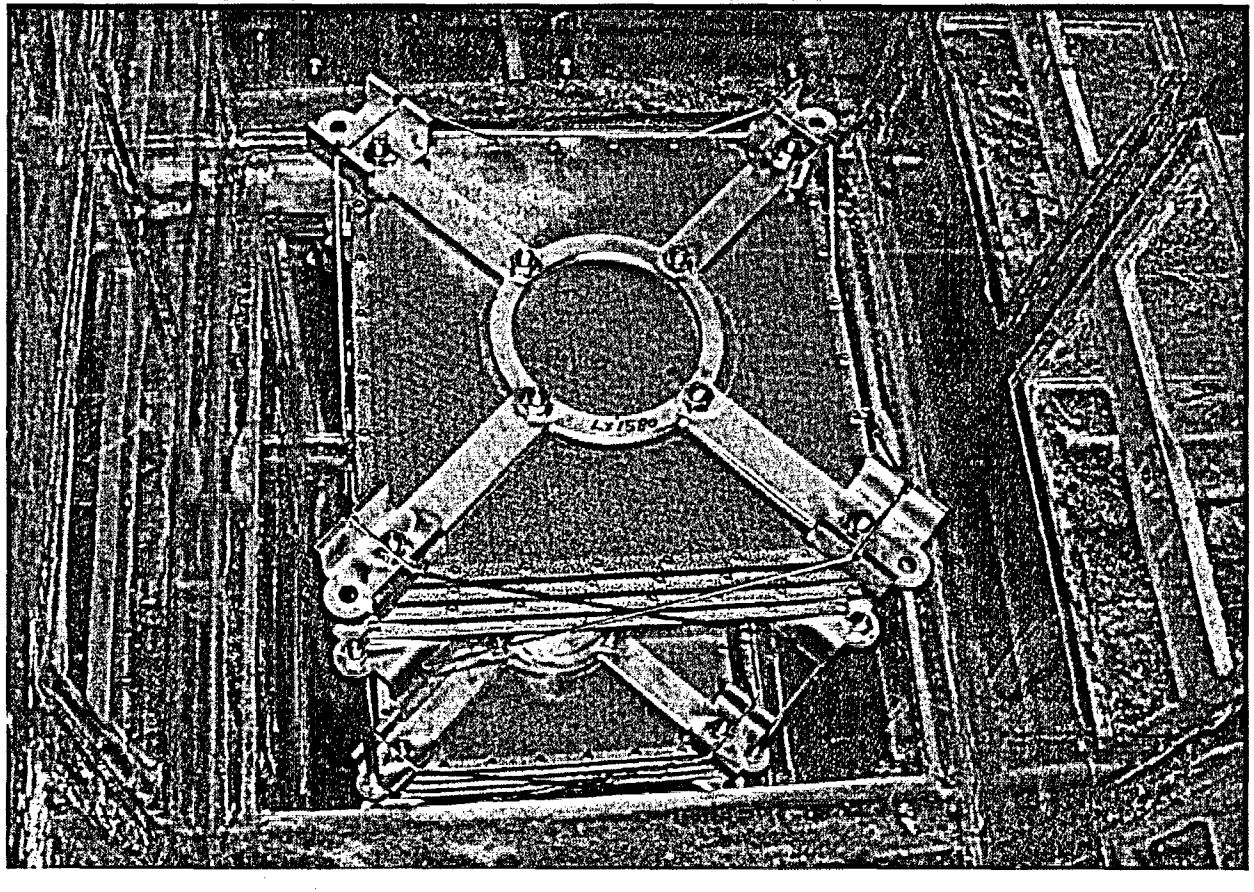
Horizontally mounted suction piping

Depressed pit

Vertically mounted suction piping

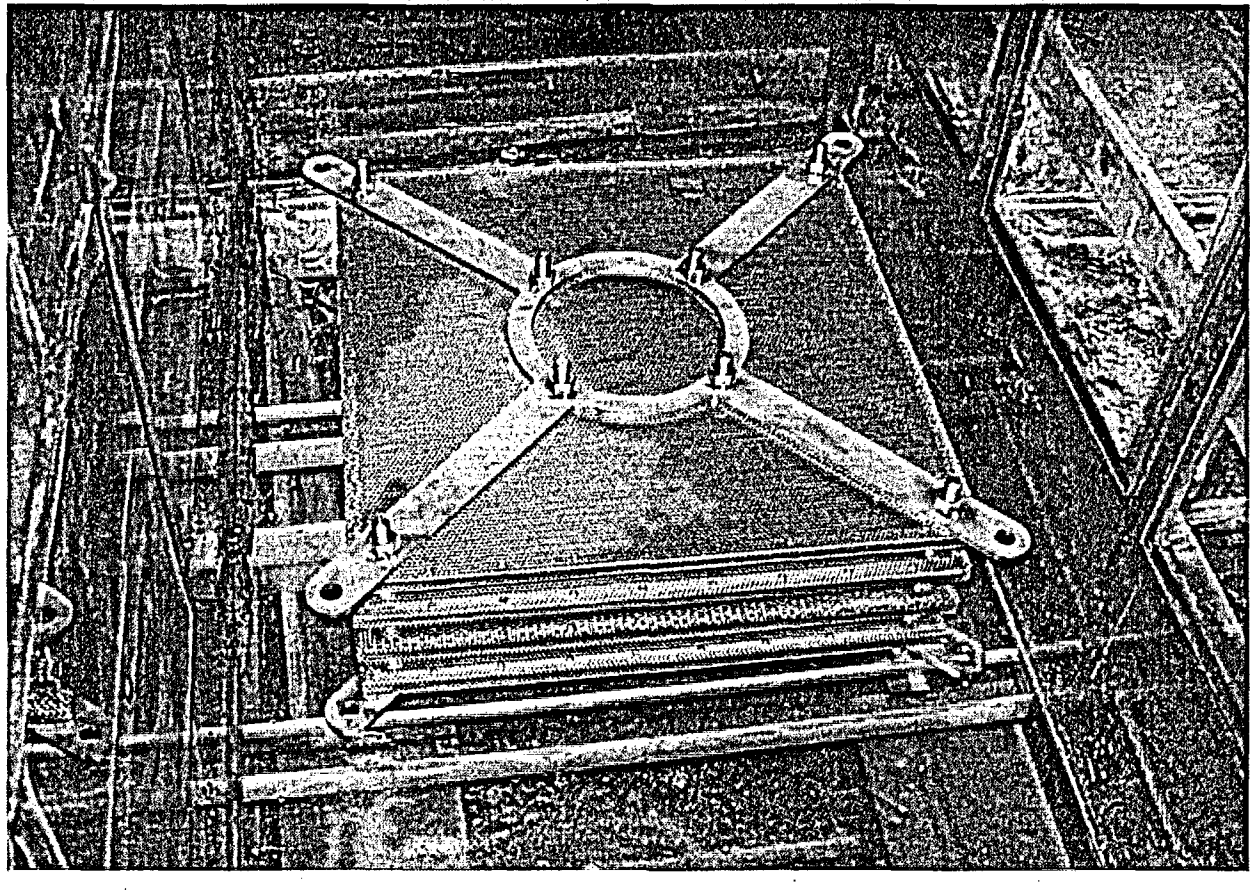
> Facilities Overview

- ***Prototype Strainer Installed in Depressed Pit***



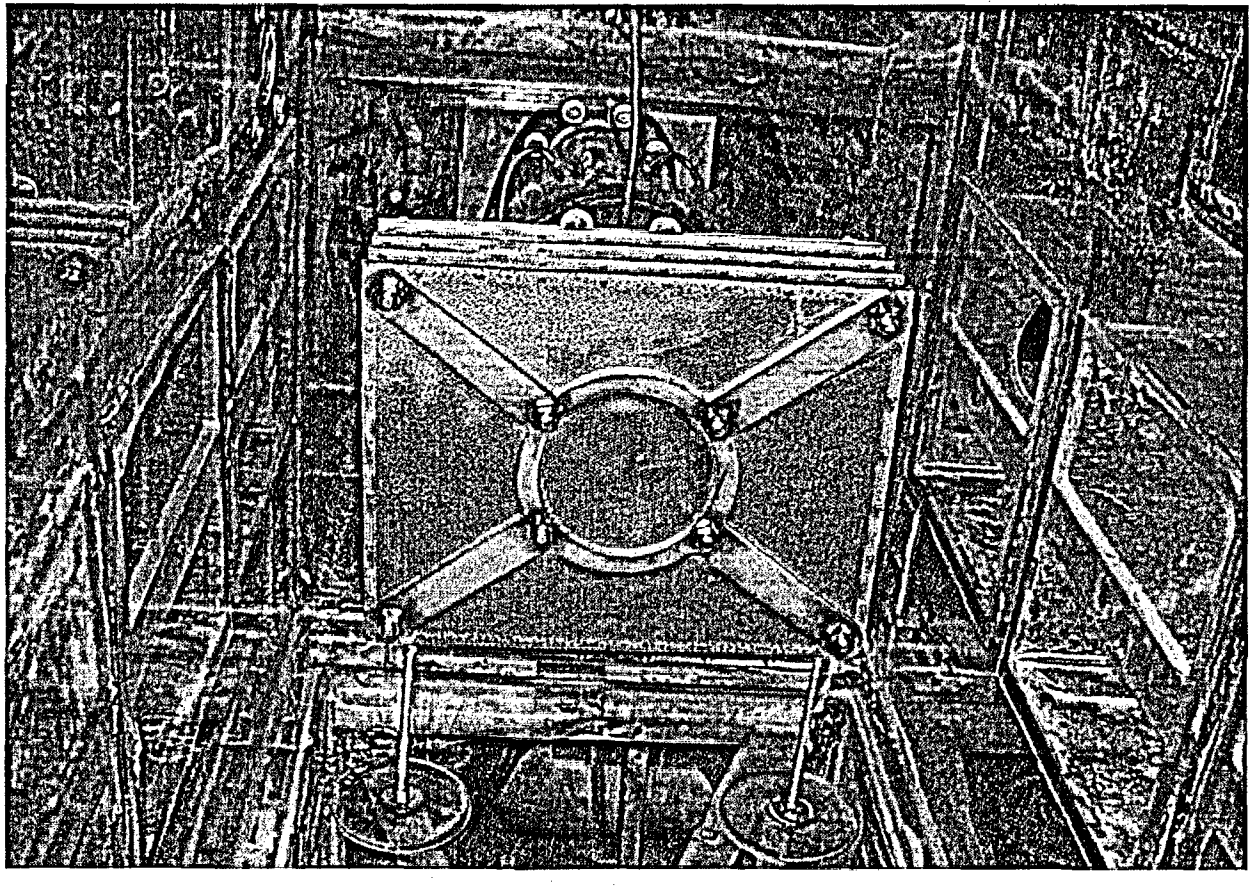
> Facilities Overview

- *Prototype Strainer Installed Vertically*



> Facilities Overview

- *Prototype Strainer Installed Horizontally*



GENERAL TOPICS

> Strainer Design Parameters

- Plant design flow rates: 2,200 – 19,100 gpm
- Approach velocities: 0.0033 – 0.0272 ft/s
- Total plant screen areas: 770 – 7,500 ft^2
- Strainer hole diameters: 0.045 – 0.095 in

> Testing Parameters

- Test flow rates: 15 – 120 gpm
- Approach velocities: 0.0033 – 0.0272 ft/s

GENERAL TOPICS

> List of Licensees

- Wolf Creek
- Callaway
- Point Beach 1 & 2
- South Texas 1 & 2
- Prairie Island 1 & 2
- Kewaunee
- Sequoyah 1 & 2
- Watts Bar
- Comanche Peak 1 & 2
- Palisades

> Status

- Six units fabricated and delivered to date
- Nine units in progress for U.S. PWRs
- Design basis debris load testing is complete

GENERAL TOPICS

> Important parameters affecting head loss

- Approach velocity at the screen surface
- Debris mix (quantity & type)
- Use of overhead nozzles
  (used to keep fine debris in suspension)
- Debris preparation

Head Loss is Plant Specific

GENERAL TOPICS

> Key test observations

- Tags, tape & labels, RMI and paint chips do not collect on the screen
- Measured head losses are less than predicted – very few test combinations resulted in head loss that approached NUREG/CR-6224 predictions

SCALING METHODOLOGY

> Geometry

- Test protocol evolved over the course of testing (debris placement, use of overhead nozzles, etc.) with no significant maximum head loss differences
- Strainer sizes being installed by clients based on "space available" or preliminarily sized per NUREG/CR-6224
  - No strainer size reductions made as a result of testing
- Actual plant accident condition submergence used in test
- Test flow conditions reflected plant flow condition at or near the strainer

SCALING METHODOLOGY

> Temperature

- Ambient temperature water used for testing
  - Water temperature recorded during test

- Measured head loss at ambient temperature adjusted to the design basis temperature using the corresponding dynamic viscosities
  - Consistent with testing previously performed for BWRs

SCALING METHODOLOGY

> Modular Strainer Setup

- Scale fraction for test debris and test flow is the ratio of test strainer surface area to plant strainer surface area

- Sensitivity tests were conducted at calculated circumscribed flow rates (for plants with high fiber conditions) – this required increasing the test flow rate through the screen surface area

DEBRIS PREPARATION METHODOLOGY

> Debris weighed dry
> Water added to debris and mechanically mixed
> Surrogate material selection based on size, shape, density, & precedent with BWR evaluations

DEBRIS INTRODUCTION METHODOLOGY

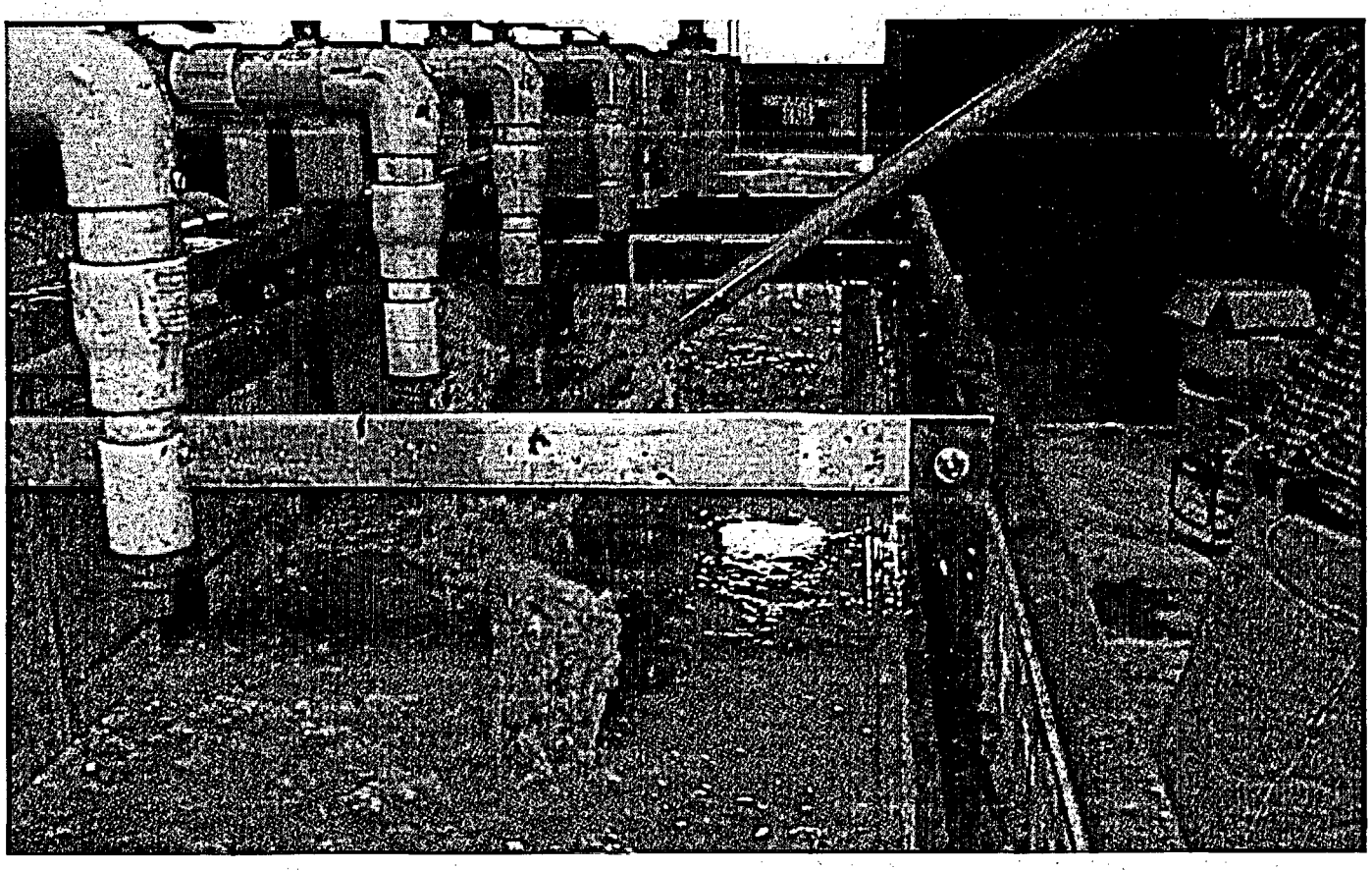
> Sequence

- Debris introduced into the flume in the following order
  - RMI – added first to prevent trapping lighter debris
  - Particulate - all
  - Fibrous
  - Latent Fiber
  - Chemical Precipitates
- Manual mixing performed prior to test start to facilitate the formation of a homogeneous debris mix
- Overhead nozzles provided mixing energy during test

DEBRIS INTRODUCTION METHODOLOGY

> Sequence

- Manual mixing performed prior to test start to facilitate the formation of a homogeneous debris mix



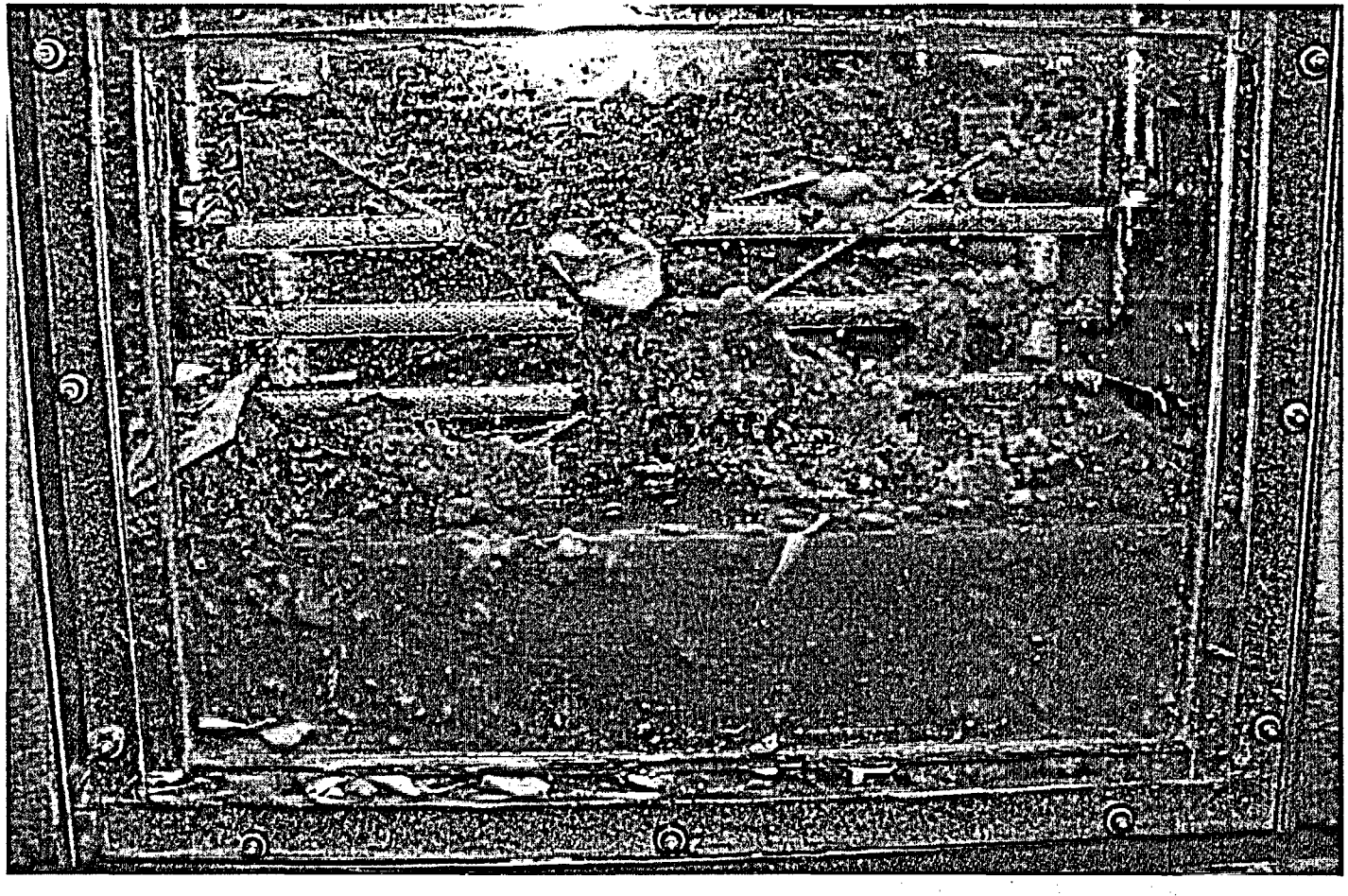
DEBRIS INTRODUCTION METHODOLOGY

> Location

- Debris introduction into test flume
  - 3-15 feet upstream of strainer
  - Within 3 feet upstream of strainer
  - Directly on the strainer (excluding RMI) and within 1 foot around the strainer
- Sensitivity testing confirmed similar head losses are achieved regardless of protocol but more time is required to reach the final head loss when the debris is placed away from the screen
  - Overhead nozzles provide mixing energy intended to keep debris materials suspended/moving in the flow stream approaching the strainer a key reason for this result

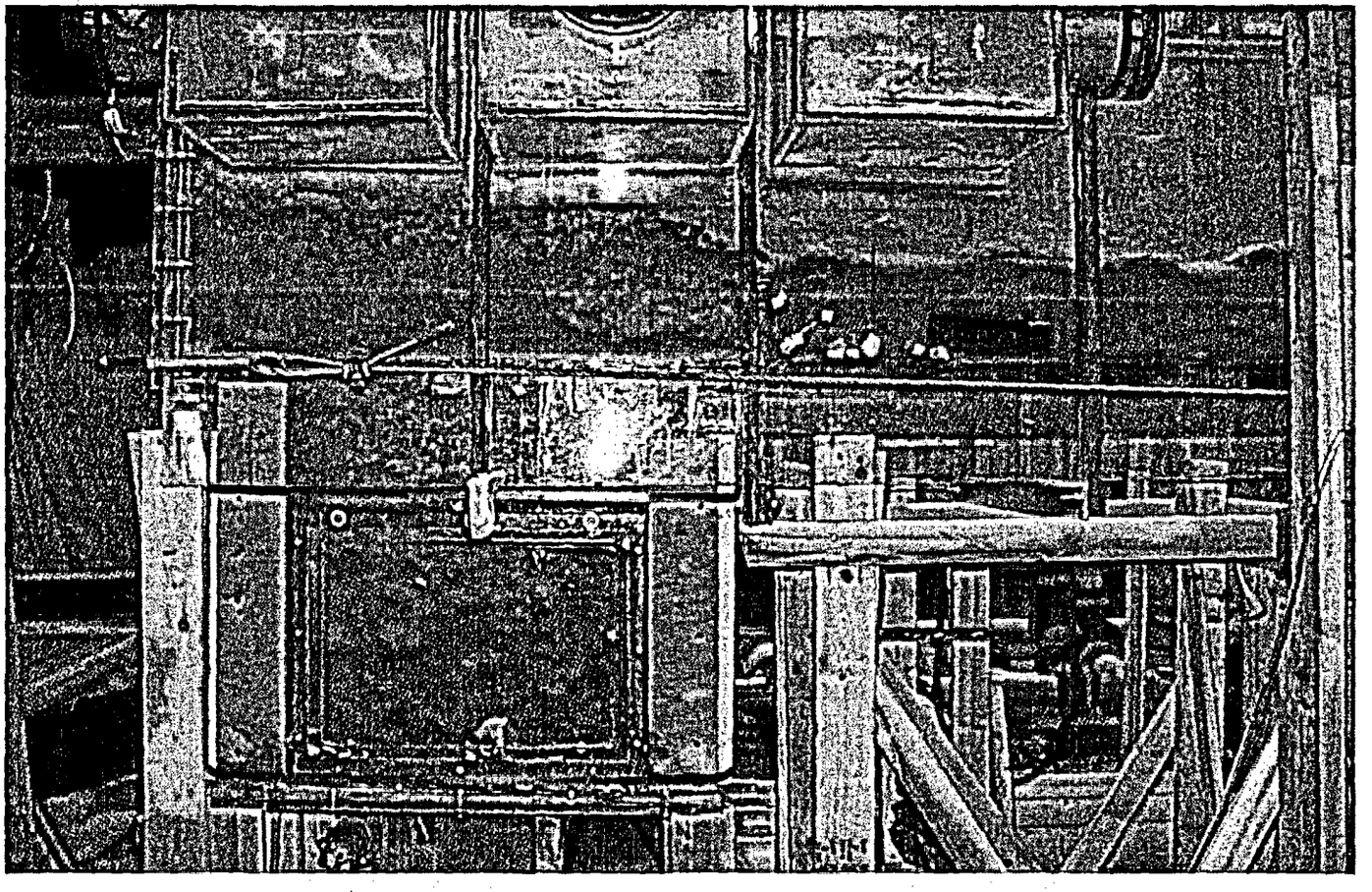
DEBRIS INTRODUCTION METHODOLOGY

Strainer mounted in a depressed pit



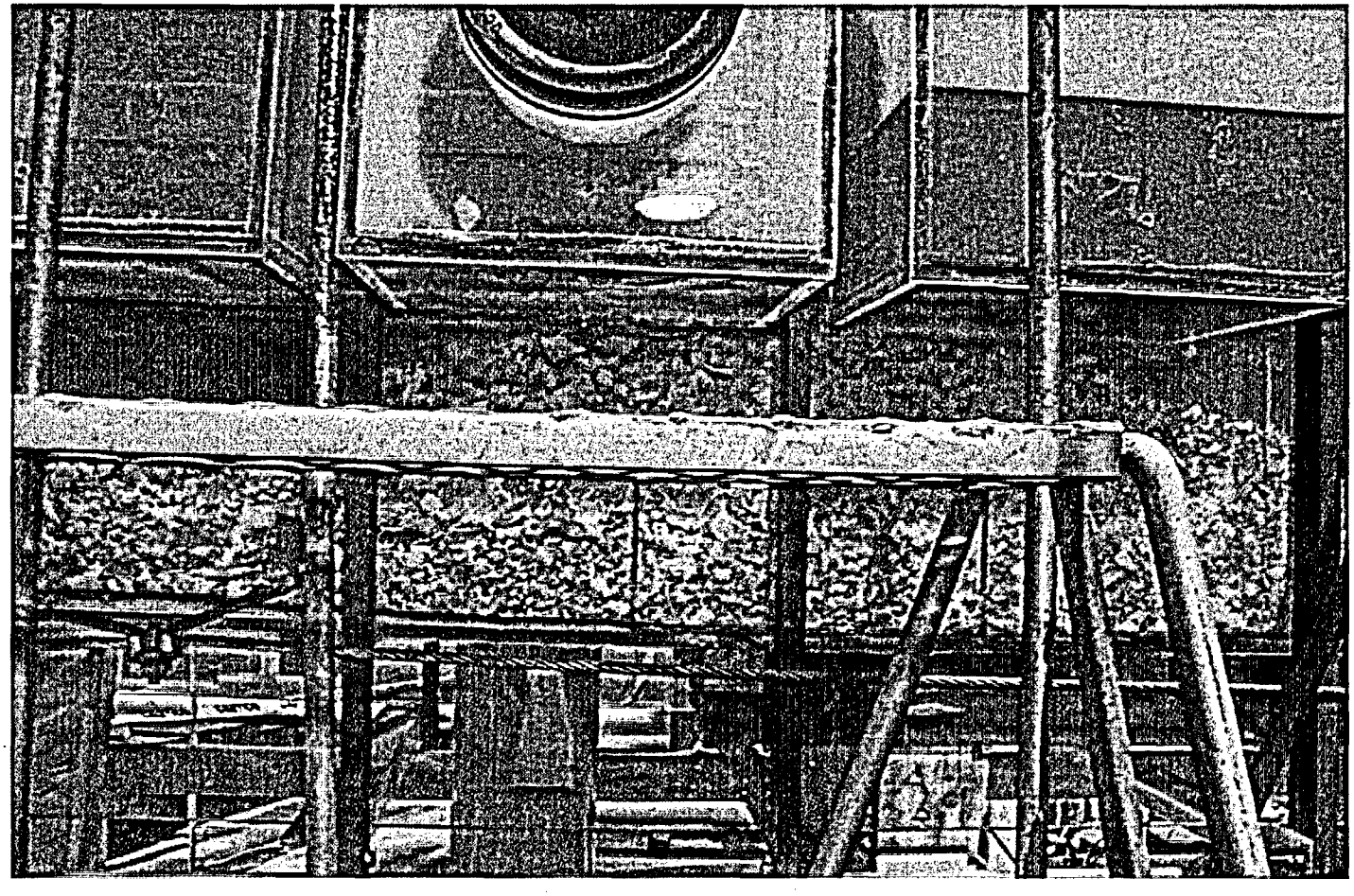
DEBRIS INTRODUCTION METHODOLOGY

Strainer mounted in a depressed pit buried in fibrous debris



DEBRIS INTRODUCTION METHODOLOGY

Strainer mounted horizontally buried in paint chips (no fiber)



TESTING SUMMARY

Plant	Test	Test Description	[4]Flow Rate Plant (gpm)	[4]Flow Rate Design Test (gpm)	[4]Flow Rate Circumscribed Test (gpm)	Debris Placement	Overhead Nozzles	Screen Area Plant (ft^2)	Screen Area Testing (ft^2)	Screen Hole Φ (Inch)	Screen Approach Vel (ft/s)
[1]A	1	LOCA Design Condition - Max Fiber Content	6,900 12,420	26.7 66.3	101.8	3 to 5 ft upstream of the strainer	2, 4, 6, 8, and 10 used	3,992.80	20.23	0.095	0.0040 0.0073
	2	LOCA Design Condition - Low Fiber Content Thin Bed Regime	6,900 12,420	26.7 66.3	101.8	Within 3 ft of the strainer	2, 4, 6, 8, and 10 used	3,992.80	20.23	0.095	0.0040 0.0073
	3	LOCA Design Condition - No Fiber with Paint Chips	6,900 12,420	26.7 66.3	101.8	Within 3 ft of the strainer (paint chips poured on the strainer)	2, 4, 6, 8, and 10 used	3,992.80	20.23	0.095	0.0040 0.0074
	4	MSLB Design Condition - Max Fiber Content	7,520	40.2	61.6	3 to 5 ft upstream of the strainer	2, 4, 6, 8, and 10 used	3,992.80	20.23	0.095	0.0044
	5	Piggy-Back Test of Test 1 with Additional 26.7 lbm of NUKON	6,900 12,420	26.7 66.3	101.8	Within 3 ft of the strainer	2, 4, 6, 8, and 10 used	3,992.80	20.23	0.095	0.0040 0.0073
B	1	LBLOCA-Max Fiber Content with Coatings as Powders	14,040	55.5	110 (Note 7)	Within 3 ft of the strainer	2, 4, 6, 8, and 10 used. 50% of pump discharge through 0.75" nozzles extended below water surface.	3,595.60	14.2	0.095	0.0087
	2	LBLOCA-Thin Bed Regime with Coatings as Powders	14,040	55.5	N/A	Within 3 ft of the strainer	2, 4, 6, 8, and 10 used. 50% of pump discharge through 0.75" nozzles extended below water surface.	3,595.60	14.2	0.095	0.0087
	3	LBLOCA Testing Paint Chips with Latent Fibers Only	14,040	55.5	N/A	Within 3 ft of the strainer	2, 4, 6, 8, and 10 used. 50% of pump discharge through 0.75" nozzles extended below water surface.	3,595.60	14.2	0.095	0.0087
	4	SBLOCA Design Condition Design Basis (Combined with Test 5)	7,100	28	N/A	Within 3 ft of the strainer	2, 4, 6, 8, and 10 used. 100% of pump discharge through 0.75" nozzles extended below water surface.	3,595.60	14.2	0.095	0.0044
	5	SBLOCA Design Condition Design Basis (Combined with Test 4)	7,100	28	N/A	Within 3 ft of the strainer	2, 4, 6, 8, and 10 used. 100% of pump discharge through 0.75" nozzles extended below water surface.	3,595.60	14.2	0.095	0.0044
[2]C	1	Design Basis Case	19,100	67.6	N/A	3 to 15 ft upstream of the strainer	Not used	4,550	16.1	0.085	0.0094
	2	Limiting Coating Size Case	19,100	67.6	129 (Note 8)	3 to 15 ft upstream of the strainer	Not used	4,550	16.1	0.085	0.0094
	3	Maximum Coating Inventory Case	19,100	67.6	123 (Note 9)	3 to 15 ft upstream of the strainer	Not used	4,550	16.1	0.085	0.0094
	5	Limiting Coating Size Case with 3M-M20C Removed	19,100	67.6	N/A	3 to 15 ft upstream of the strainer	Not used	4,550	16.1	0.085	0.0094

Notes:

[1]During the recirculation phase for the LOCA Design Condition, the water level in containment increases over time. The maximum initial flow rate is 4,900 gpm; however once the designated water level is reached the maximum flow rate is 12,420 gpm. Testing for this strainer modeled the increase in flow rates. The proposed plant screen area available for testing was reduced by 200 ft^2 for unknown tags and labels.

[2]Test 4 was bound by Test 3. Therefore, Test 4 testing criteria was not tested.

[4]The Testing Flow Rate column provides the target flow rate. Actual flow rates are greater than or equal to the target flow rate.

[6]The measured HL of approximately 0.024 ft was very near instrument calibration error. Therefore, the instrumentation sensed the measured HL as values between approximately 0.024 ft and 0 ft. This caused high fluctuation in the reading of the percent change of average HL in five minutes. However, the slope of HL verses time was reasonably constant.

[7]After the termination of Test 1, the flow rate was increased to approximately double the design flow for testing. The results were recorded for informational purposes only.

[8]After the termination of Test 2, 0.15 # of NUKON was added in the vicinity of the strainer. Headloss was measured at design flowrate and circumscribed flowrate (approximately doubled the design flowrate). The results were recorded for informational purposes only.

[9]After the termination of Test 3, the debris was pushed ontop of the strainer to completely covered the strainer. Headloss was measured at design flowrate and circumscribed flowrate (approximately doubled the design flowrate). The results were recorded for informational purposes only.

TESTING SUMMARY

Plant	Test	Test Description	[4]Flow Rate Plant (gpm)	Design Test (gpm)	Circumscribed Test (gpm)	Debris Placement	Overhead Nozzles	Screen Area Plant (ft^2)	Testing (ft^2)	Screen Hole Φ (inch)	Screen Approach Vel (ft/s)
D	1	Design Basis Case (Coatings Fail as Powder)	4,000	63.5	N/A	Within 3 ft of the strainer	3 nozzles furthest from the strainer used at 15 gpm each.	768.7	12.2	0.066	0.0116
	2	Design Basis Case (Coatings Fail as Chips & Powder)	4,000	63.5	N/A	Within 3 ft of the strainer	1, 3, 5, 7, and 9 used at 63.5 gpm each.	768.7	12.2	0.066	0.0116
	3	Thin Bed Regime (Low Fiber)	4,000	63.5	N/A	Within 3 ft of the strainer	1, 3, 5, 7, and 9 used at 63.5 gpm each.	768.7	12.2	0.066	0.0116
E	1	Design Basis Case	2,200	17.9	40.4	1 ft around and upstream of the strainer	2, 4, 6, 8, and 10 used. Nozzles extended below water surface.	1,496.70	12.2	0.066	0.0033
	2	Low Fiber Test Case	2,200	17.9	N/A	1 ft around and on top of the strainer	2, 4, 6, 8, and 10 used. Nozzles extended below water surface.	1,496.70	12.2	0.066	0.0033
F	1	Design Basis Case with Current Configuration	5,200	76.7	N/A	Debris placed 1 to 3 feet upstream of the strainer	5 nozzles closest to the strainer used.	827.3	12.2	0.085	0.014
	2	Design Basis with Redundant Screen	2,600	76.7	N/A	Debris placed 1 to 3 feet upstream of the strainer	5 nozzles closest to the strainer used.	413.7	12.2	0.085	0.014
G	1	LBLOCA Max Fiber Content with Coatings as Powders	8,830	66.4	110	On Top of the Strainer	2, 4, 6, 8, and 10 used. 50% of pump discharge was through nozzles extended below water surface.	3,279.5	24.67	0.045	0.006
	2	LBLOCA Thin Bed Regime with Coatings as Powders	8,830	66.4	N/A	On Top of the Strainer	2, 4, 6, 8, and 10 used. 50% of pump discharge was through nozzles extended below water surface.	3,279.5	24.67	0.045	0.006
	3	LBLOCA Design Basis with Coatings as Powders	8,830	66.4	N/A	On Top of the Strainer	2, 4, 6, 8, and 10 used. 50% of pump discharge was through nozzles extended below water surface.	3,279.5	24.67	0.045	0.006
	4	LBLOCA Testing Paint Chips without Fibers	8,830	66.4	N/A	On Top of the Strainer	2, 4, 6, 8, and 10 used. 50% of pump discharge was through nozzles extended below water surface.	3,279.5	24.67	0.045	0.006
	5	SBLOCA Design Basis with Coatings as Powders	1,500	10.1	N/A	On Top of the Strainer	2, 4, 6, 8, and 10 used. Nozzles extended below water surface.	3,129.8	21.06	0.045	0.0011
H	1	Design Basis Case	18,750	82.2	N/A	3 to 15 ft upstream of the strainer	Not used	1,537.50	6.74	0.095	0.0272
	2	Limiting Coating Size Case	18,750	82.2	N/A	3 to 15 ft upstream of the strainer	Not used	1,537.50	6.74	0.095	0.0272
	3	Maximum Coating Inventory Case	18,750	82.2	N/A	3 to 15 ft upstream of the strainer	Not used	1,537.50	6.74	0.095	0.0272
	4	Maximum Latent (Fiber) Debris Case	18,750	82.2	N/A	3 to 15 ft upstream of the strainer	Not used	1,537.50	6.74	0.095	0.0272

Notes:

[4]The Testing Flow Rate column provides the target flow rate. Actual flow rates are greater than or equal to the target flow rate.

TESTING SUMMARY

Plant	Test	Debris Head Loss: At Design Flow Rates	Debris Head Loss: At Circumscribed Flow Rates	Avg Test Temp (°F)	Prototype Strainer Test Termination: [5]Termination Criteria	Prototype Strainer Test Termination: % change of Head Loss at Termination	[3]Debris Sequence
[1]A	1	0.005 ft @ 26.1 gpm 0.285 ft @ 66.65 gpm	0.462 ft @ 101.94 gpm	46.7	Standard	-0.106	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	2	0.043 ft @ 27.3 gpm 0.482 ft @ 66.6 gpm	0.879 ft @ 102 gpm	45.9	Standard	-0.21	Particulate debris, fibrous debris, latent fibers, then chemical debris (No RMI)
	3	0 ft @ 26.92 gpm 0.012ft @ 67.33 gpm	0.022 ft @ 102.16 gpm	44.9	Standard	-0.024	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	4	0.009 ft @ 43.07 gpm	0.018 ft @ 62.32 gpm	43.9	Test terminated prior to the 5 required flume volume turnovers since the head loss did not change for the 2.2 turnovers the flume volume experienced.	0.194	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	5	0.032 ft @ 67 gpm	0.091 ft @ 101.88 gpm	50.4	Standard	0.045	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
B	1	0.561 ft @ 55.97 gpm	2.5897ft @ 110.66gpm (Note 7)	49	Standard	0.053	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	2	1.004 ft @ 55.77 gpm	N/A	47.2	Standard	-0.162	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	3	0.003 ft @ 56.01 gpm	N/A	47.2	Standard	0.113	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	4	N/A	N/A	N/A	Test terminated due to air injestion. This test was then combined with Test 5.	N/A	Particulate debris, fibrous debris, latent fibers, then chemical debris (No RMI)
	5	0.331 ft @ 28.61 gpm	N/A	49.2	Standard	0.081	Particulate debris, fibrous debris, latent fibers, then chemical debris (No RMI)
[2]C	1	0.011 ft @ 68.2 gpm	N/A	49.5	Standard	See Note 6	RMI added first then the remaining debris added.
	2	0.016 ft @ 67.9 gpm 0.101 ft @ 68 gpm (Note 8)	0.27 ft @ 129 gpm (Note 8)	51.5	Standard	0.465	RMI added first then the remaining debris added.
	3	0.049 ft @ 67.9 gpm 0.03 ft @ 68 gpm (Note 9)	0.20 ft @ 123 gpm (Note 9)	51.3	Standard	-0.347	RMI added first then the remaining debris added.
	5	0.019 ft @ 67.9 gpm	N/A	53.1	Standard	-0.021	RMI added first then the remaining debris added.

Notes:

[1]During the recirculation phase for the LOCA Design Condition, the water level in containment increases over time. The maximum initial flow rate is 4,900 gpm; however once the designated water level is reached the maximum flow rate is 12,420 gpm. Testing for this strainer modeled the increase in flow rates. The proposed plant screen area available for testing was reduced by 200 ft^2 for unknown tags and labels.

[2]Test 4 was bound by Test 3. Therefore, Test 4 testing criteria was not tested.

[3]RMI debris constituents were not placed directly on the strainer surface.

[5]The Standard Termination Criteria for the prototype strainer testing was: (1) Increase in 5 minutes average measured headloss less than 1% AND (2) calculated time for flume recirculation five times has been reached.

[6]The measured HL of approximately 0.024 ft was very near instrument calibration error. Therefore, the instrumentation sensed the measured HL as values between approximately 0.024 ft and 0 ft. This caused high fluctuation in the reading of the percent change of average HL in five minutes. However, the slope of HL verses time was reasonably constant.

[7]After the termination of Test 1, the flow rate was increased to approximately double the design flow for testing. The results were recorded for informational purposes only.

[8]After the termination of Test 2, 0.15 # of NUKON was added in the vicinity of the strainer. Headloss was measured at design flowrate and circumscribed flowrate (approximately doubled the design flowrate). The results were recorded for informational purposes only.

[9]After the termination of Test 3, the debris was pushed ontop of the strainer to completely covered the strainer. Headloss was measured at design flowrate and circumscribed flowrate (approximately doubled the design flowrate). The results were recorded for informational purposes only.

TESTING SUMMARY

Plant	Test	Debris Head Loss: At Design Flow Rates	Debris Head Loss: At Circumscribed Flow Rates	Avg Test Temp (°F)	Prototype Strainer Test Termination: [5]Termination Criteria	Prototype Strainer Test Termination: % change of Head Loss at Termination	[3]Debris Sequence
D	1	0.017 ft @ 63.88 gpm	N/A	45.9	Standard	0.104	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	2	0.089 ft @ 64.02 gpm	N/A	45.6	Standard	0.077	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	3	3.15 ft @ 63.96 gpm	N/A	45.3	Standard	0.118	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
E	1	0.110 ft @ 18.57 gpm	2.489 ft @ 41.07 gpm	57.2	Standard	-0.012	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	2	0.546 ft @ 18.69 gpm	N/A	54.9	Standard	0.023	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
F	1	7.766 ft @ 76.86 gpm	N/A	48	Standard	-0.069	RMI added first then the remaining debris added.
	2	12.115 ft @ 76.87 gpm	N/A	48.9	Standard	-0.155	RMI added first then the remaining debris added.
G	1	0.098 ft @ 66.78 gpm	0.113 ft @ 119.66 gpm	45.2	Standard	0.027	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	2	0.268 ft @ 67.57 gpm	N/A	43.6	Standard	-0.892	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	3	4.490 ft @ 66.59 gpm	N/A	43.7	Standard	0.078	Particulate debris, fibrous debris, latent fibers, then chemical debris (No RMI)
	4	0 ft @ 67.08 gpm	N/A	44	Standard	-0.396	RMI, particulate debris, fibrous debris, latent fibers, then chemical debris
	5	0 ft @ 12.47 gpm	N/A	43.6	Standard	0	Particulate debris, fibrous debris, latent fibers, then chemical debris (No RMI)
H	1	0.014 ft @ 82.42 gpm	N/A	53.7	Standard	-0.471	RMI added first then the remaining debris added.
	2	0.010 ft @ 82.53 gpm	N/A	53.3	Standard	-0.062	RMI added first then the remaining debris added. Nukon added last.
	3	0.007 ft @ 82.67 gpm	N/A	46.3	Standard	0.236	Debris randomly placed in flume (No RMI for this test) latent fiber last.
	4	0.017 ft @ 82.48 gpm	N/A	51.5	Standard	0.041	No RMI added. Fiber added last.

Notes:

[3]RMI debris constituents were not placed directly on the strainer surface.

[5]The Standard Termination Criteria for the prototype strainer testing was: (1) Increase in 5 minutes average measured headloss less than 1% AND (2) calculated time for flume recirculation five times has been reached.

HEAD LOSS DUE TO CHEMICAL EFFECTS

> Overall Approach

- Chemical precipitate selection and concentration based on guidance from:
  - Industry Corrosion & Thermodynamic Modeling Guidance (NUREG/CR-6873)
  - ICET Results (dependent on plant-specific debris mix and moderator)
  - WCAP-16530-NP as amended (used to validate the calculated quantity of each chemical precipitate formed)
  - Plant-specific data (including debris mix & quantity, area & location of aluminum, moderator, pH & temp vs. time, sump volume)

HEAD LOSS DUE TO CHEMICAL EFFECTS

> Overall Approach

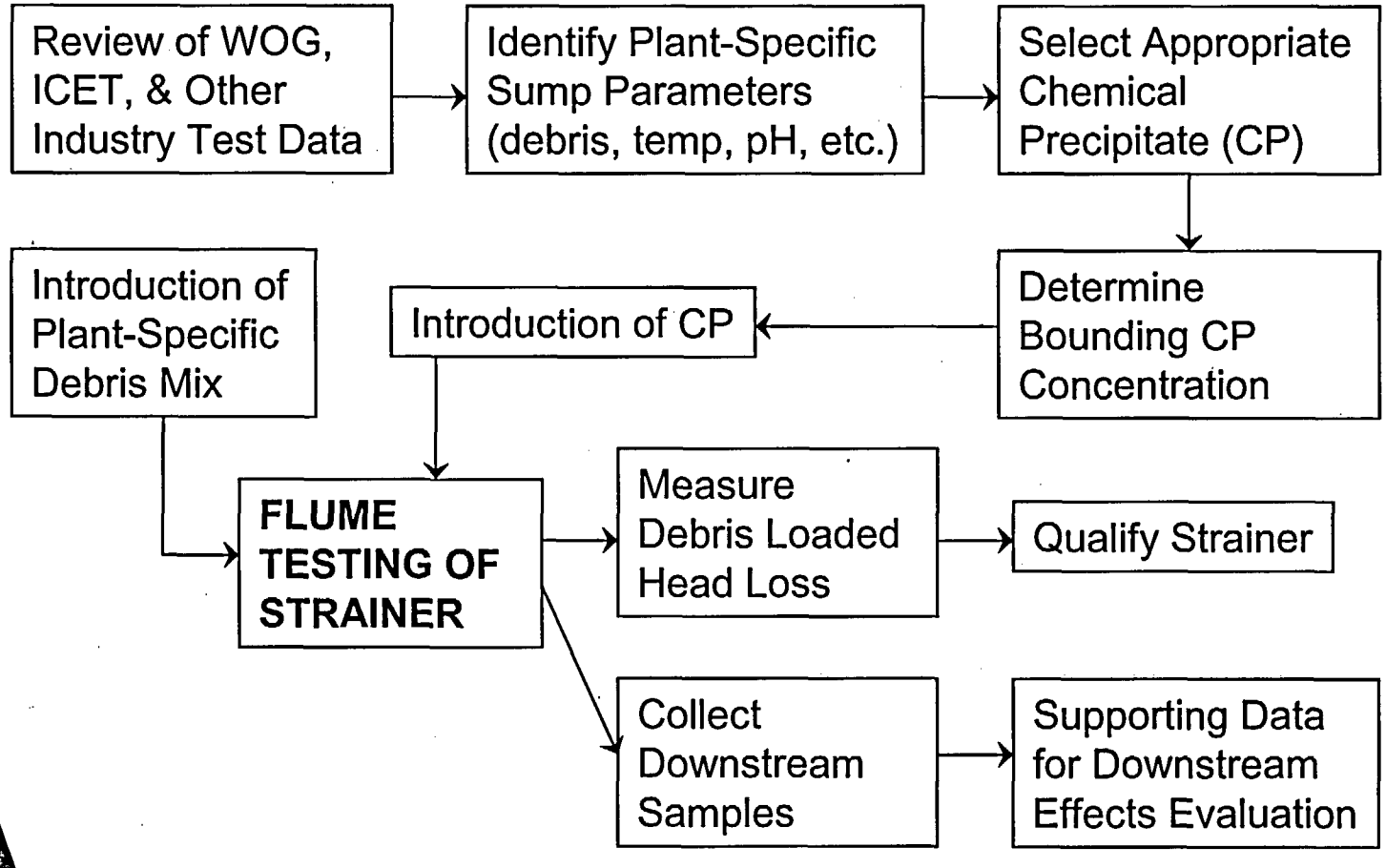
- Introduction of actual chemical byproducts in strainer tests using manufactured materials which represent chemical compounds expected to precipitate during accident conditions

> Head Loss Due to Chemical Precipitates

- Chemical precipitate materials added to the flume along with other debris sources for an integrated test
- Chemical precipitates added as the last debris constituent prior to mixing and starting of the recirculation pump

HEAD LOSS DUE TO CHEMICAL EFFECTS

> Integration of Chemical Effects Results



HEAD LOSS DUE TO CHEMICAL EFFECTS

> Representative Environment

- Testing was performed using tap water at ambient temperatures
  - Consistent with testing performed for BWR strainers
  - Previous industry testing indicated that temperature effects on head loss closely correlated to the ratio of dynamic viscosities at the corresponding temperatures
  - Head loss results are later adjusted to account for the difference between the test temperature and accident conditions

HEAD LOSS DUE TO CHEMICAL EFFECTS

> **Surrogate Materials**
- Inorganic Zinc – Tin Powder
- Epoxy – Walnut Shell Flour
- Obsolete Coating Systems – Current Coating Systems
- Latent Debris – SER Recipe

- Technical justification for the use of these materials during testing is included as part of the strainer qualification package

HEAD LOSS DUE TO CHEMICAL EFFECTS

> Chemical Precipitates

- Actual chemical byproducts utilized
  - Sodium Aluminum Silicate ($NaAlSi_3O_8$)
  - Calcium Carbonate ($CaCO_3$)
  - Aluminum Hydroxide ($Al(OH)_3$)
  - Calcium Phosphate ($Ca_3(PO_4)_2$)

- Procured manufactured materials to ensure the correct compound/formula as guided by industry research
  - Utilized best available information
  - No accepted surrogate or chemical precipitation recipe had been identified at the time of the tests

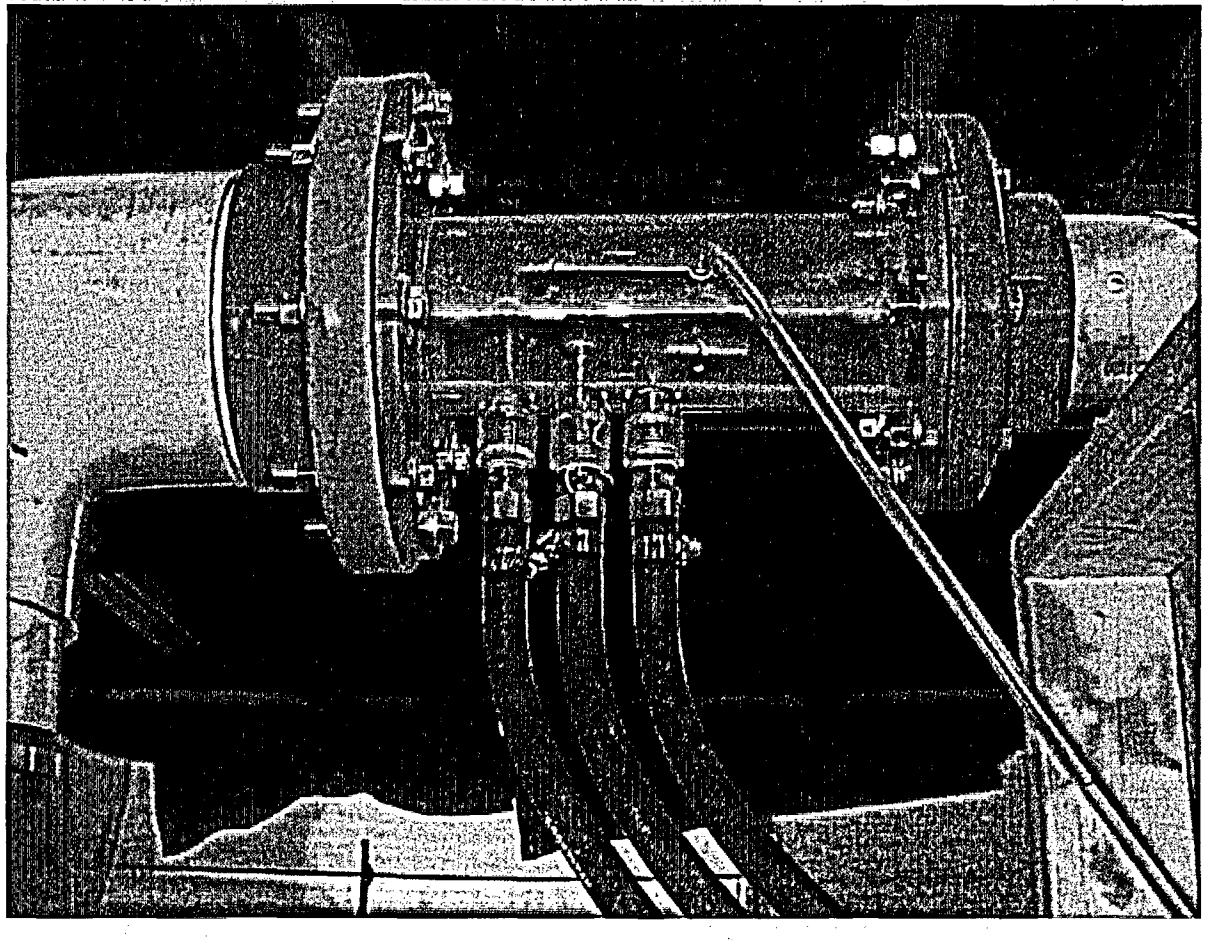
SCREEN PENETRATION TEST

> Penetration Test Overview

- Three isokinetic sampling ports located in the 6 inch flow loop downstream of the pressure taps used to measure strainer head loss
- Each port independently controlled by a shut-off valve
- Sampling discharge nozzles positioned vertically at an elevation such that the flow velocity at each sampling port inlet is the same as the velocity in the 6 inch pipe
- Samples taken at 10 minute intervals during first hour of testing and at 20 minute intervals thereafter

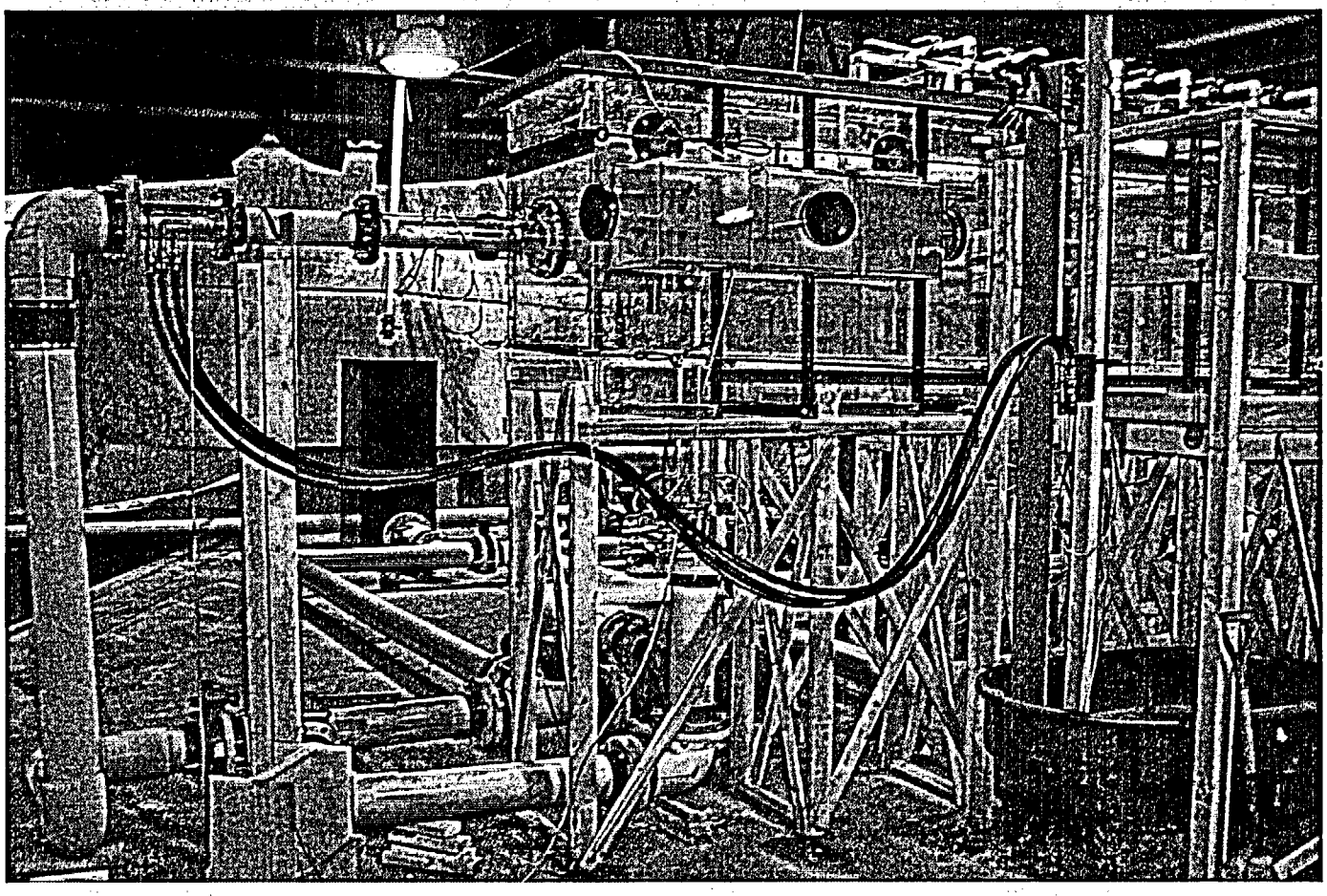
SCREEN PENETRATION TEST

Isokinetic Downstream Sampling Ports



SCREEN PENETRATION TEST

Isokinetic Downstream Sampling System



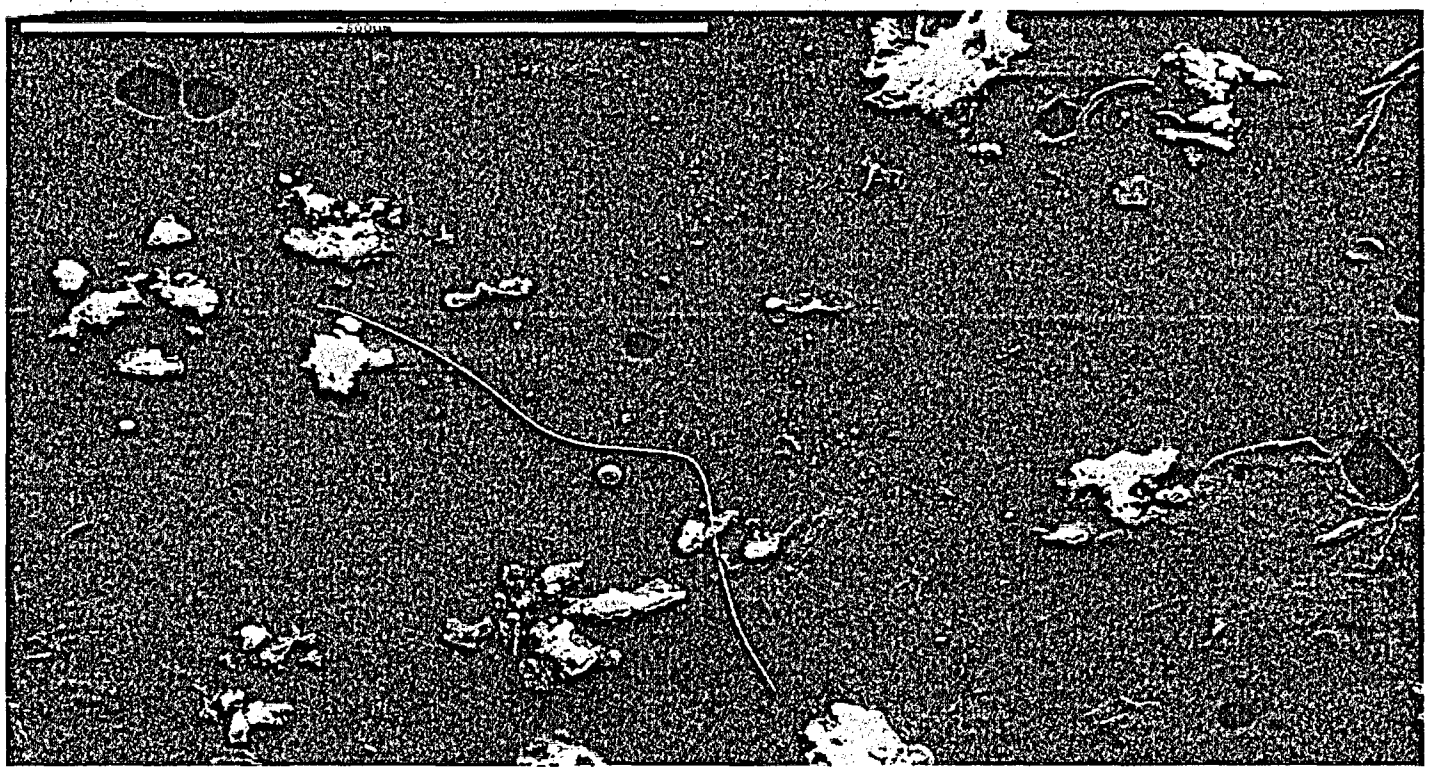
SCREEN PENETRATION TEST

> Integrated Head Loss & Penetration Test

- Samples analyzed via Scanning-Electron-Microscopy (SEM) provide data related to a specific head loss test
- RV internals evaluation provides an acceptance criteria for pressure loss and does not specify acceptable debris constituents or quantities
- ECCS components evaluation (for wear and plugging) uses WCAP-16406-P guidance and testing experience based on transported debris loads.

SCREEN PENETRATION TEST

Downstream Sample Using Scanning-Electron-Microscopy



TERMINATION CRITERIA

> Test termination criteria based on BWR experience

- Increase in 5 minute average measured head loss less than 1%

AND

- Calculated time for flume recirculation five times has been reached

> Data extrapolation using rate of change for head loss at test termination provides a reasonable estimate for extending data

TERMINATION CRITERIA

Sample Computer Screen at Termination

% change in 5 minutes average HL

5 minutes average HL

Head loss (ft)

REPLACEMENT STRAINERS

> Samples of replacement strainers

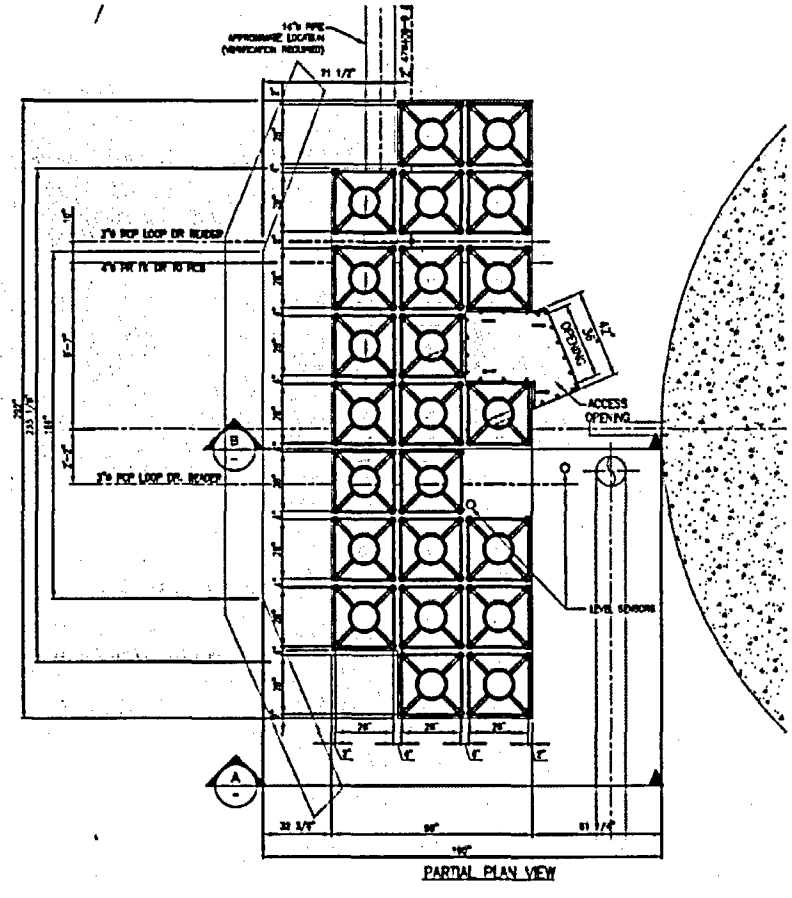
- Early conceptual designs
- Photographs of replacement strainers in the fabrication facility during trial fit-up

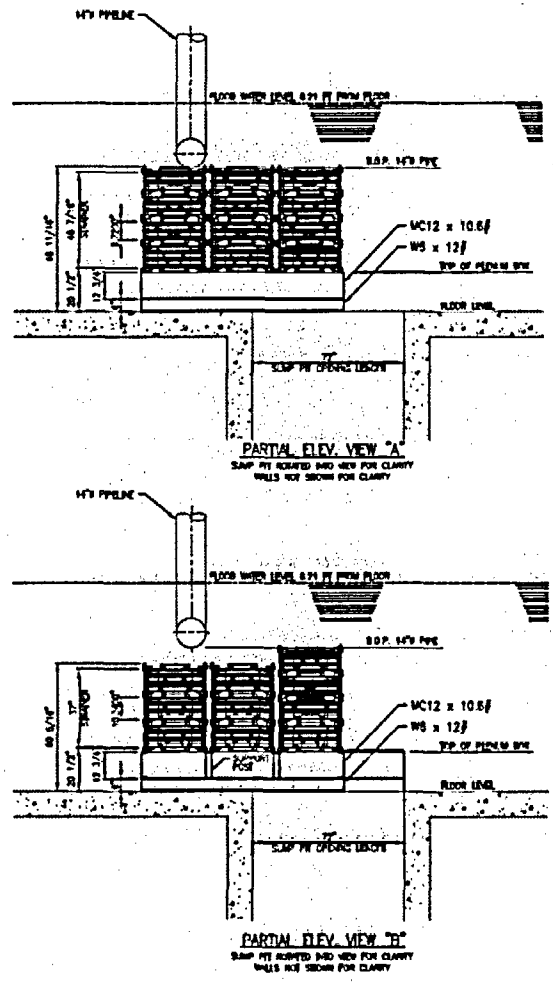
  or

- Photographs of replacement strainers installed

REPLACEMENT STRAINERS

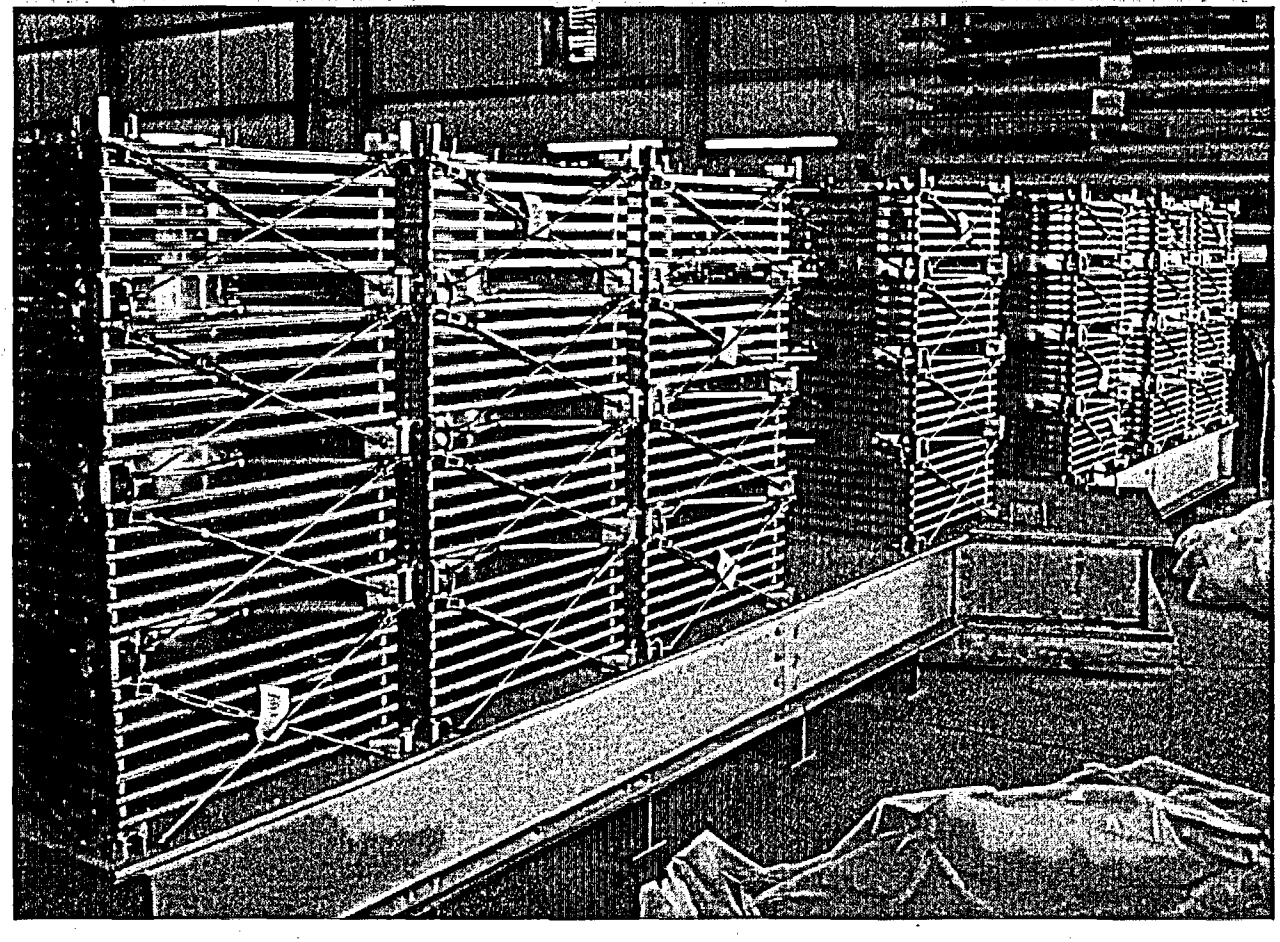
Plant V Early Replacement Strainer Design





REPLACEMENT STRAINERS

Plant V Replacement Strainers at the Fabrication Facility

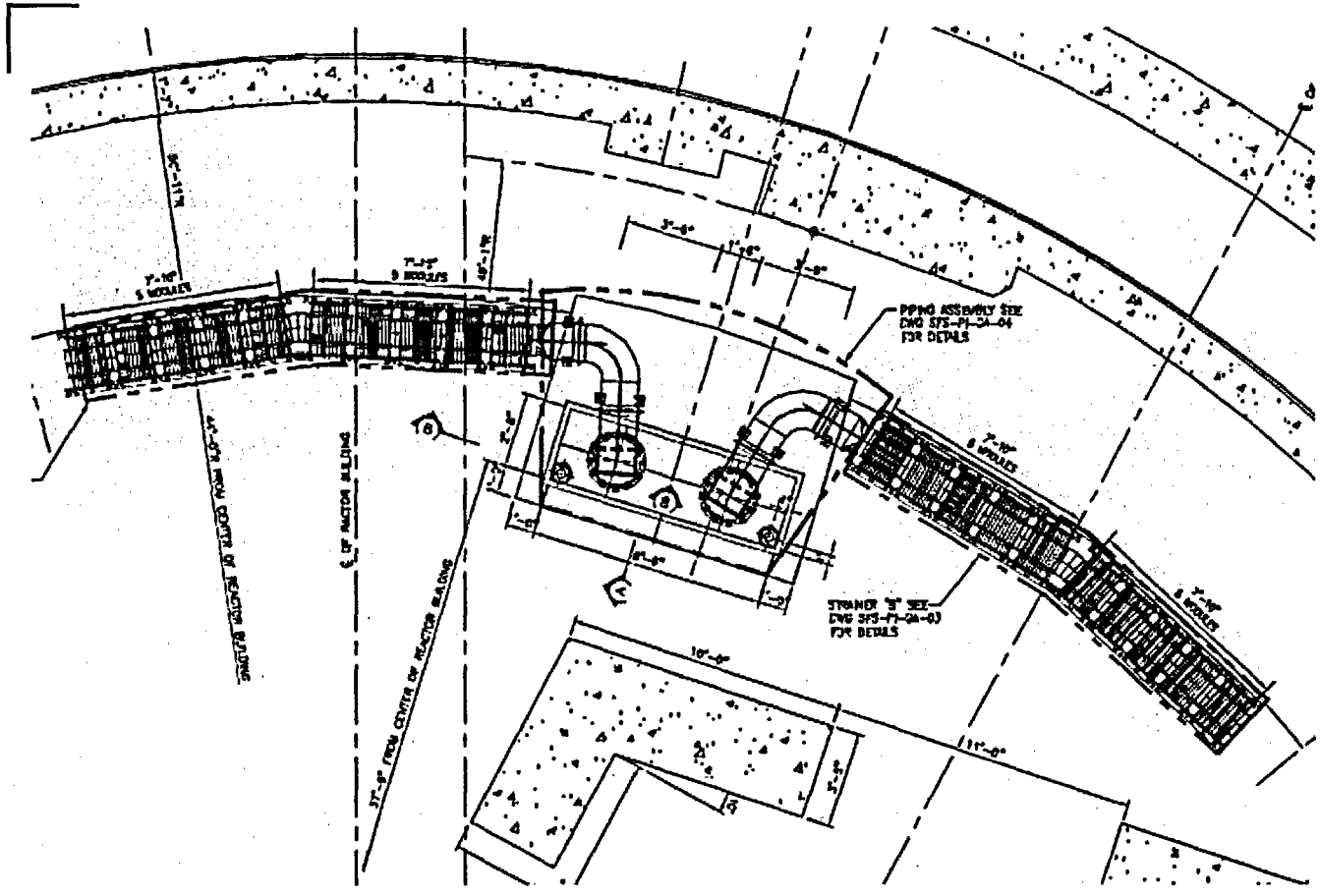


REPLACEMENT STRAINERS

Plant V Replacement Strainers at the Fabrication Facility

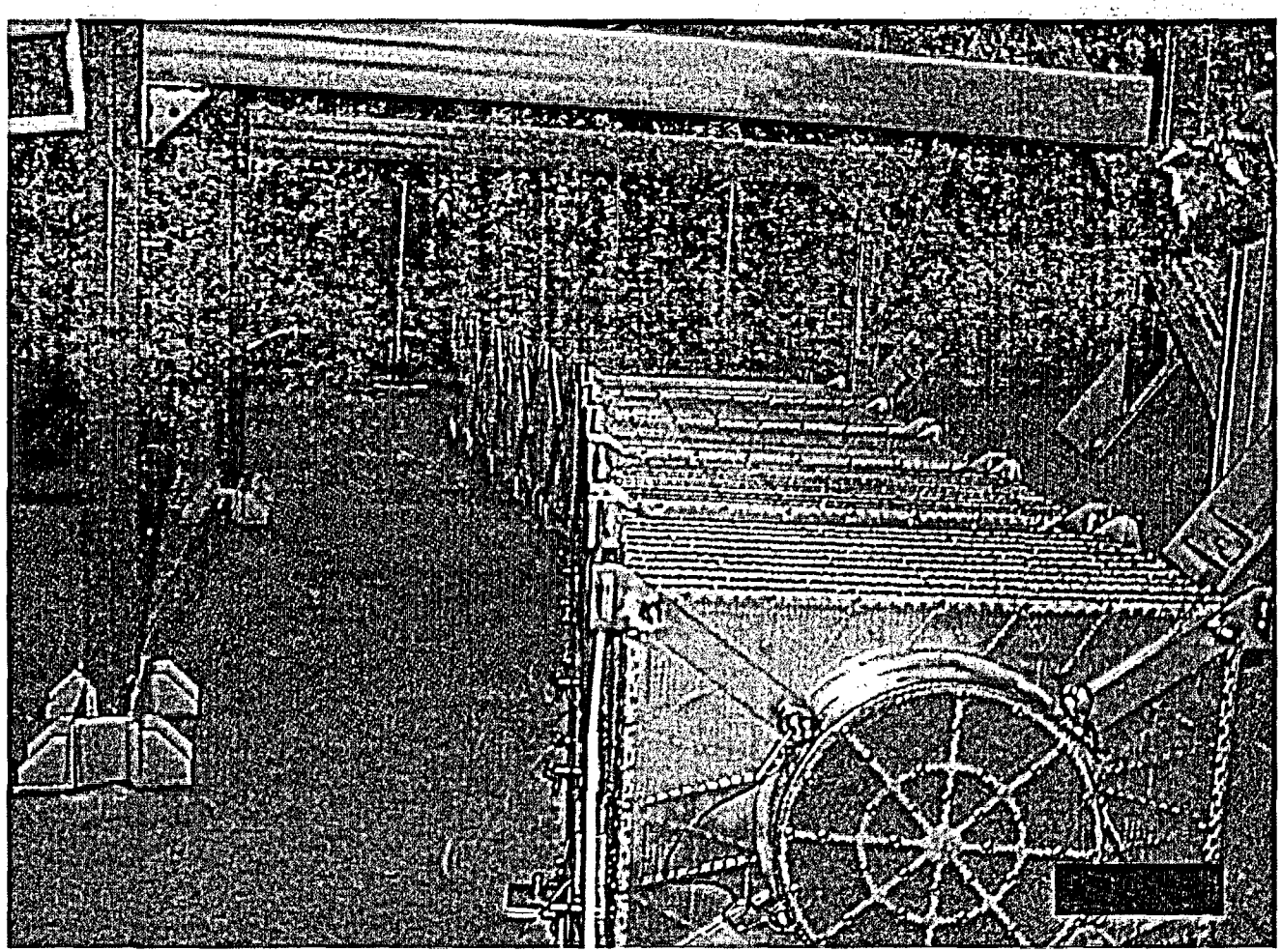
REPLACEMENT STRAINERS

Plant X Early Replacement Strainer Design



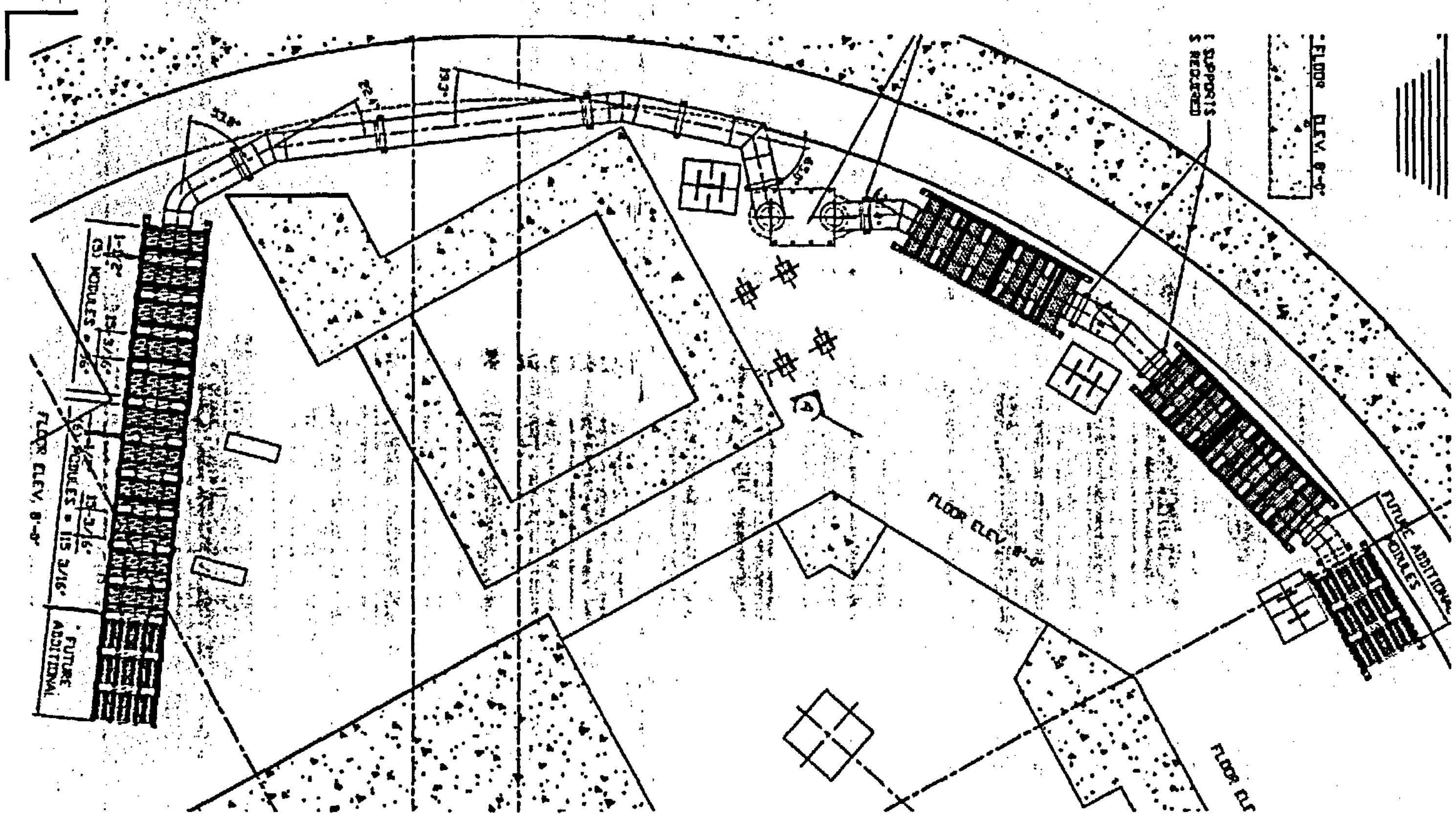
REPLACEMENT STRAINERS

Plant X Replacement Strainers Installed in the Plant



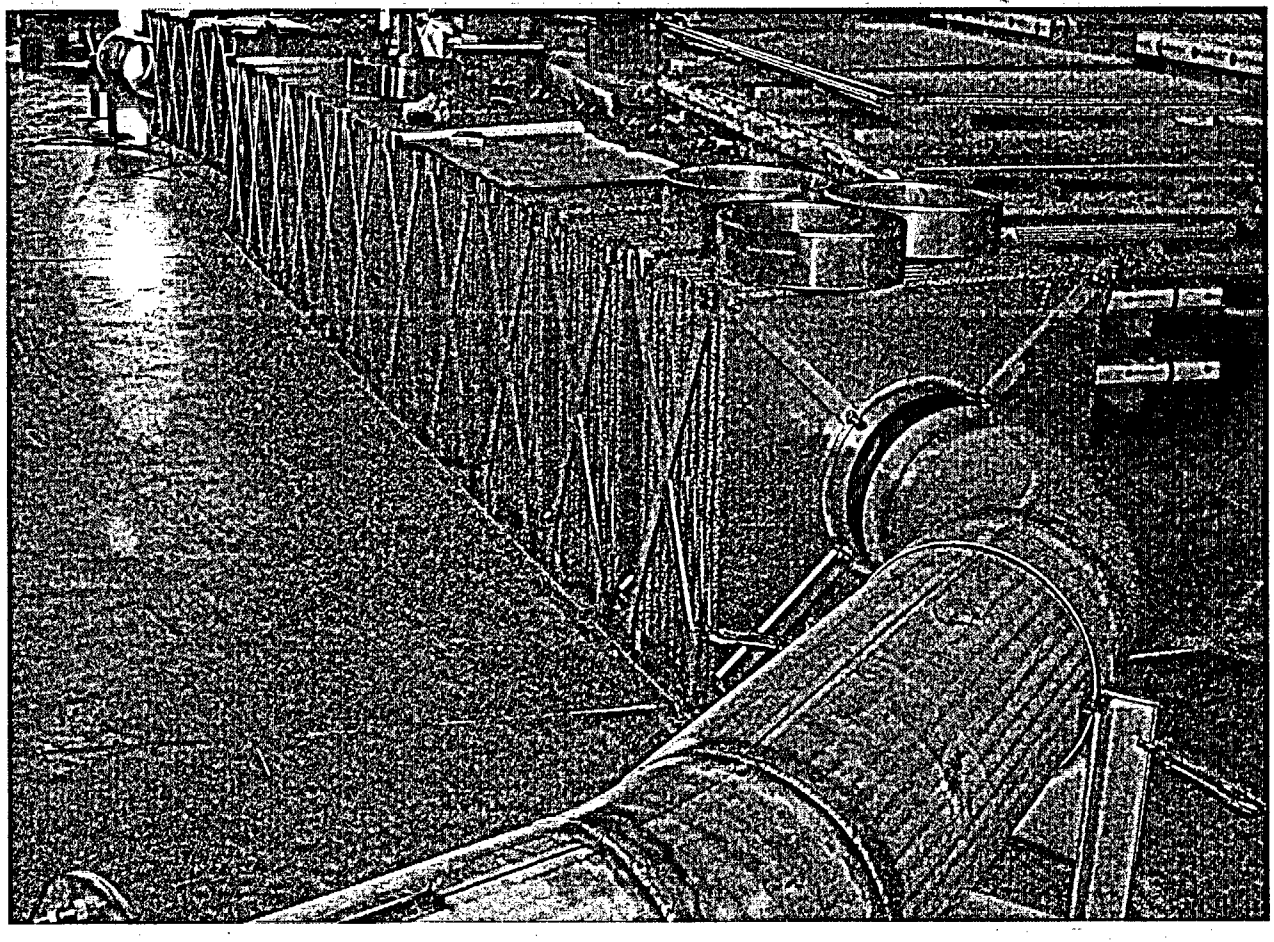
REPLACEMENT STRAINERS

Plant Y Early Replacement Strainer Design



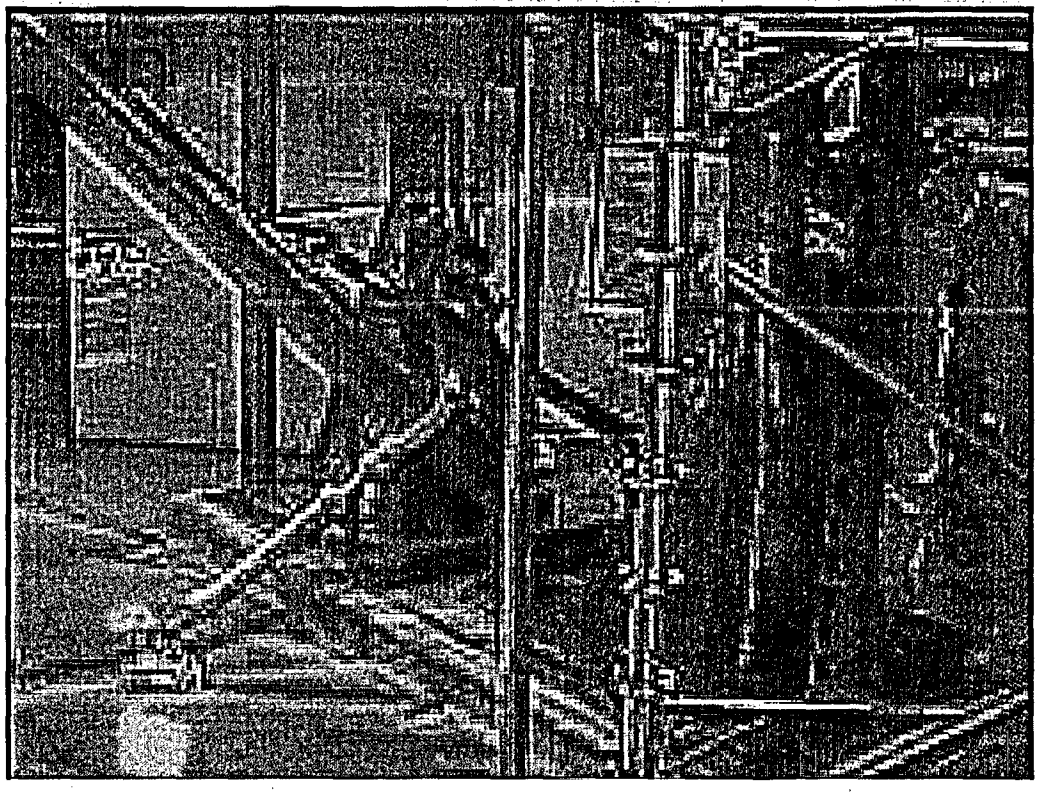
REPLACEMENT STRAINERS

Plant Y Replacement Strainers at the Fabrication Facility



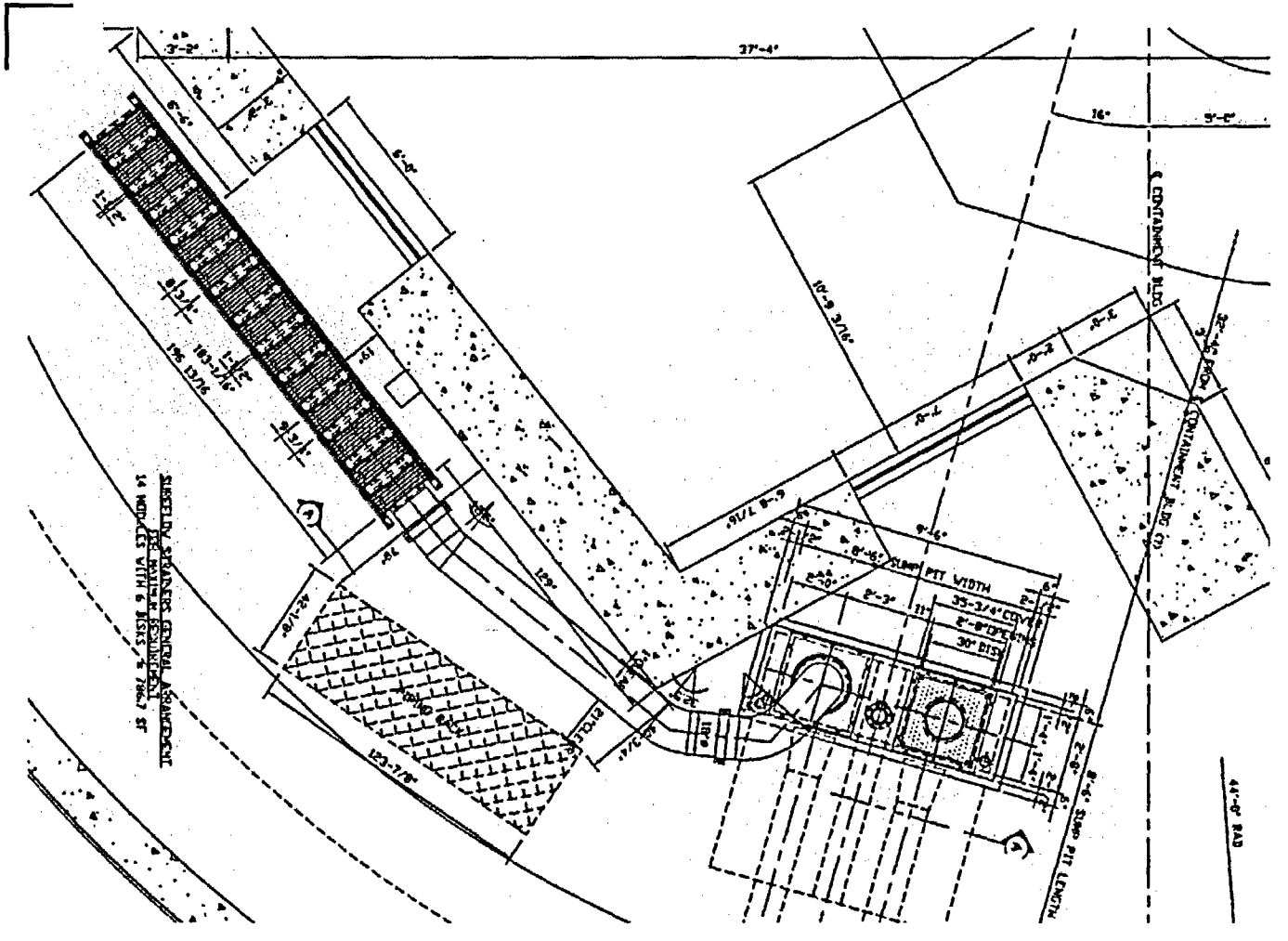
REPLACEMENT STRAINERS

Plant Z Original Strainers in the Plant



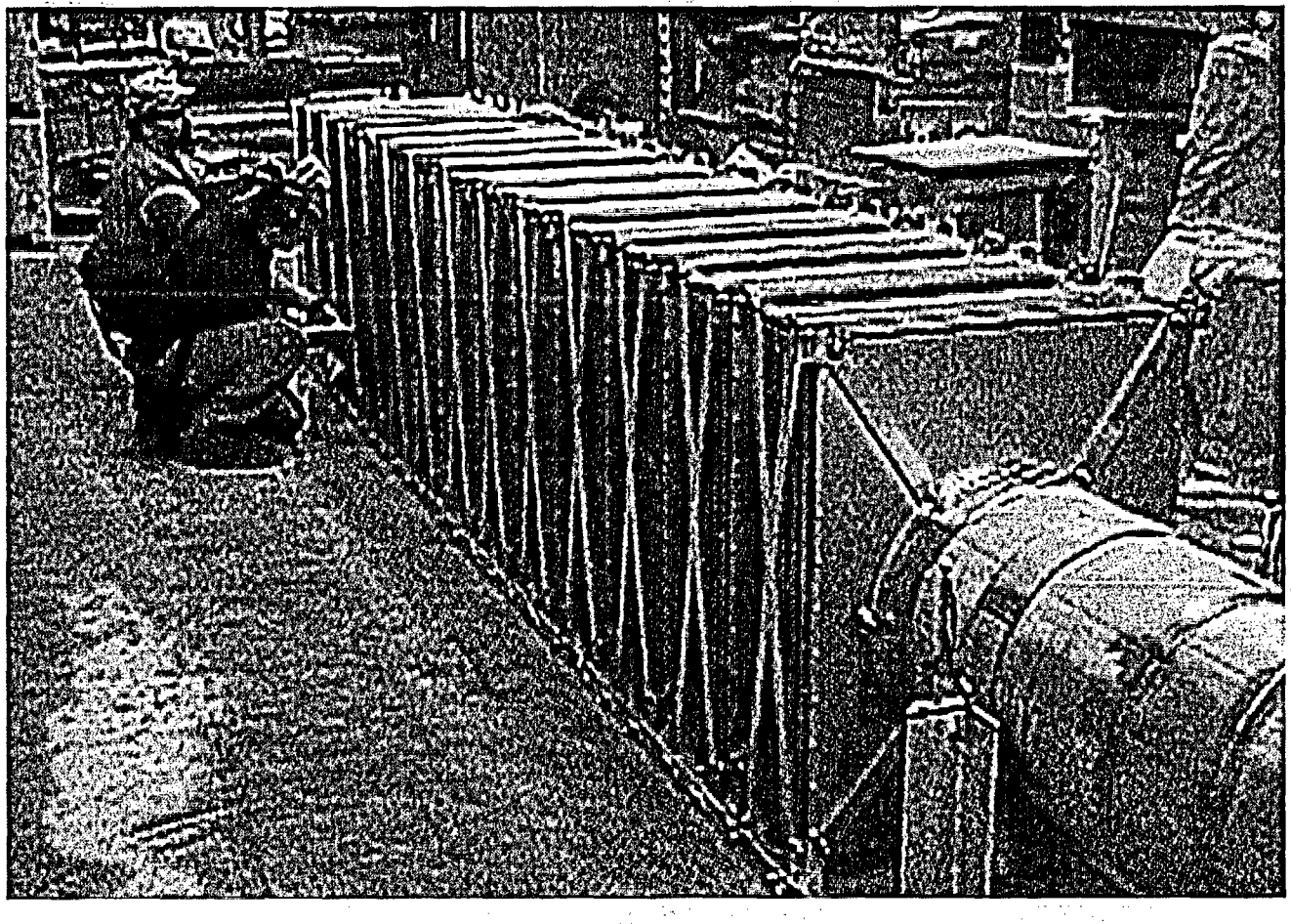
REPLACEMENT STRAINERS

Plant Z Early Replacement Strainer Design



REPLACEMENT STRAINERS

Plant Z Replacement Strainers at the Fabrication Facility



SUMMARY

> Strainer testing evolved over time
- Based on BWR precedent
- Conservative assumptions made at each level

> Replacement strainers from 25 to 75 times existing screen areas utilizing very robust designs

> Downstream effects evaluations ongoing

> NRC Staff questions acknowledged
- Working with licensees to address by various means