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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

August 23, 2006

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

SUBCOMMITTEE ON THERMAL HYDRAULICS

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MEETING

OPEN SESSION

+ + + + +

WEDNESDAY,

AUGUST 23, 2006

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ROCKVILLE, MARYLAND

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The Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., Graham B. Wallis, Chairman, presiding.

COMMITTEE MEMBERS PRESENT:

GRAHAM B. WALLIS, Chairman

MARIO V. BONACA, Member

THOMAS S. KRESS, Member

OTTO L. MAYNARD, Member

I-N-D-E-X

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

(10:14 a.m.)

[Meeting in progress.]

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

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

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

CHAIRMAN WALLIS: Do you have a theory?

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

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

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

are different fibers out there we have tested. To date we have tested mineral and Nukon.

CHAIRMAN WALLIS: And so you have a predictive capability. You can say if you have a certain area of screen and certain hole size, then you --

MR. SMITH: For our strainer, we are predicting this is the quantity of material and this is the characteristic. So in that --

CHAIRMAN WALLIS: About how much of it gets through?

MR. SMITH: We are down into small cubic feet, you know, one cubic foot of glass.

CHAIRMAN WALLIS: For all the strainers or per strainer?

MR. SMITH: Oh, this is for the complete --

CHAIRMAN WALLIS: Complete assembly in the plant?

MR. SMITH: Yes. And I'll show you -- we have another feature. We have a feature we have added to our strainer, and we do a second. But I'll keep going, and I'll --

This is just a little filter picture here showing the beginning of our test. We introduced the

fiber in very small batches to allow it to accumulate on the strainer module. In this we understand that as you add little batches and little batches and little batches that gives it opportunity to pass through.

And, again, in the real world you don't know if all the fiber is going to hit it in one big slug, or you're going to hit it in little trickle streams. So we introduce it in the trickle stream fashion, giving it the most opportunity to get through.

This is a half-inch loading on it. You'll see some non-uniform loading going on. There's still clean surface area there, and we keep --

CHAIRMAN WALLIS: It looks as if it's all on the outside of the cylinder.

MR. SMITH: It has gone down the center as well.

MR. ZIGLER: If you would look in here, you would see portions of it. But the inside of the cylinder would normally be the last one to do it, because it has a tangential velocity vector on into the surface of it. So it -- actually, in the inside we see a lot of what we like to almost call it -- it's a self-cleaning phenomena, and it's the only -- when your inside gets filled in, but you finally clear this

last remaining area, which is the inside of it.

CHAIRMAN WALLIS: I don't understand the design of your strainer. You have this can, and you have something inside it, some kind of --

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

CHAIRMAN WALLIS: -- shape. And fibers can actually go inside the cylinder?

MR. SMITH: Yes. It's --

CHAIRMAN WALLIS: They could fill the whole cylinder, and they do.

MR. SMITH: They're concentric.

CHAIRMAN WALLIS: But if you fill the cylinder, then it doesn't seem to really matter. They can't get into it, so it doesn't matter --

MR. SMITH: That's right.

CHAIRMAN WALLIS: -- how much area you have inside. It just becomes limited presumably by the outside.

MR. SMITH: Outside and down through the center.

CHAIRMAN WALLIS: And when you showed us these things completely buried in debris, presumably the inside is full of debris and there's very little flow that goes through there. So having all that area

doesn't help you, then.

MR. SMITH: It accumulates the debris.

MR. ZIGLER: But, again, just remember that we are talking about a very, very highly porous bed, because the beds are uncompressed.

CHAIRMAN WALLIS: But the effective area of the screen is very different when it becomes clogged.

MR. ZIGLER: Oh, absolutely. That's the reason for that jump that you saw in the data. Absolutely.

MR. SMITH: Yes.

CHAIRMAN WALLIS: As long as you just have a little bit of fibers and all that area is useful --

MR. ZIGLER: Right.

CHAIRMAN WALLIS: -- plug up the hole inside --

MR. SMITH: Dr. Wallis, we designed the strainer with gaps and spacing between these to accommodate the debris.

CHAIRMAN WALLIS: When you say 3,000 square feet of strainer, that's all these wiggles and squiggles inside.

MR. ZIGLER: Absolutely.

CHAIRMAN WALLIS: I mean, if you just look

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

MR. SMITH: Oh, yes. Yes.

CHAIRMAN WALLIS: But that's what you're really faced with when you have a heavy load. It's the outside of --

MR. SMITH: And we base the thickness, the predicted debris load thickness on the surface area, so that we're not just jamming it all in.

CHAIRMAN WALLIS: Base it on all the -- on the superficial surface area of the cylinder, or the area of all the inside?

MR. SMITH: The inside --

CHAIRMAN WALLIS: So you have a .002 approach velocity based on all of the area --

MR. SMITH: Right.

CHAIRMAN WALLIS: -- and maybe a .001 velocity based on the cylinders themselves or something?

MR. SMITH: Exactly, yes. But as -- like I say, we have sized the strainers, the gap, the spacing between the gaps to accommodate the predicted quantity of debris that's arriving.

MEMBER MAYNARD: More debris loading the more debris you have in there, isn't it? The more modules of strainers that you put on --

MR. SMITH: Exactly. Exactly.

MEMBER MAYNARD: So it's not limited to just one --

MR. SMITH: Well, going on with our fiber bypass testing, again, most of the fiber bypass occurs when the -- again, as I stated before on the first -- the positing on the strainer. Fiber bypass essentially becomes zero once that bed completely forms. We have observed the bypass is proportional to the strainer area and the approach velocity.

The quantity of bypass, you know, can be significant. This is some bypass material we've got -- we've collected, just to show some of the material that has gone downstream of the perforated plate of our strainer.

CHAIRMAN WALLIS: And got caught on another strainer.

MR. SMITH: It's collected in a five micron bag, a bag filter, we have a bag filter section downstream. So it is collected, dried, weighed, and characterized.

MR. ZIGLER: And, in fact, the filter is very, very highly effective, that we have had to change the procedure of doing the bypass testing by first putting in a five micron bag and letting the

water circulate for a considerable amount of time to clean the water first and then we will put in the bag that we were using for the test.

CHAIRMAN WALLIS: Now, when you say "quantitative fiber bypass is significant" --

MR. SMITH: It can be significant in that --

CHAIRMAN WALLIS: -- what does that mean?

MR. SMITH: We're talking here -- we've seen a good amount of quantity from standard perforated plate on bypass, and I wanted to go on, we add a separate --

CHAIRMAN WALLIS: Well, you say "significant," but then you were telling me before that only one or two cubic feet got through in the --

MR. SMITH: That's with our secondary feature.

CHAIRMAN WALLIS: Oh, with your secondary feature.

MR. SMITH: Yes.

CHAIRMAN WALLIS: Oh, okay.

MR. SMITH: The next slide --

CHAIRMAN WALLIS: Well, when you say "significant," that means five percent gets through or something, when -- it doesn't tell me what you mean by

"significant."

MR. SMITH: I have some data I can provide you with.

CHAIRMAN WALLIS: Does one truckload get through or --

MR. SMITH: I provided the staff some information on what we had the other day, so -- it's not truckload, but it is a percentage, many cubic feet.

CHAIRMAN WALLIS: Many cubic feet.

MR. SMITH: Yes, I could say that.

CHAIRMAN WALLIS: That's enough to make a difference in the lower plenum of the reactor flume.

MR. SMITH: Yes, potentially. I don't know -- I don't know the blockage issue of that -- the fuel itself. We had a secondary feature.

MEMBER KRESS: The previous slide showing -- it looks a little strange to me. It's like the fiber had built up a layer and then broke off in chunks.

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

CHAIRMAN WALLIS: This is in the bag.

MR. SMITH: If you dump the bag out. It is --

MEMBER KRESS: That happened in the bag,

you think?

MR. ZIGLER: Oh, yes, it clumps up. It looks like puff balls --

MR. SMITH: Yes.

MR. ZIGLER: -- of fiber.

CHAIRMAN WALLIS: And it felts, presumably. Isn't it felt a little bit? It's --

MR. SMITH: Excuse me?

CHAIRMAN WALLIS: It felts. It's like felt. It --

MR. SMITH: Yes.

CHAIRMAN WALLIS: The fibers attach --

MR. ZIGLER: It's because of the long strands of fiber. I mean, the strands are pretty large.

MR. SMITH: It actually collects in our bag downstream, and this is after we dried it, dump it out, take some photos of it, we've got some characterization on it. We've added our -- we have a secondary feature we add that collects or entraps the fiber after it gets through the holes within our perforated plate.

This is basically a -- just a secondary stainless steel knitted wire mesh material, it's very porous, slide up inside of it. And, again, we've got

an inner and an outer tube here, so it's a cylinder that goes inside. So all the fiber -- or the flow passes through and then comes out this little wire mesh secondary filter.

CHAIRMAN WALLIS: Looks like a way to create high head loss.

MR. SMITH: We test all of our strainers with this material in place. Okay? So it does add some head loss, but it's not extremely high. But you do pay a little bit on your head loss, but it does a very nice job of collecting bypass of fiber. So we've used that, and that then has gotten it down to that less than a cubic foot or so. And this --

CHAIRMAN WALLIS: One wonders if you really need it to be so thick. I mean --

MR. SMITH: We have --

CHAIRMAN WALLIS: Do the fibers actually penetrate much into this porous media?

MR. SMITH: It's pretty -- a loose, loose-knit wire --

CHAIRMAN WALLIS: Most of them are on the surface.

MR. SMITH: Yes, they go down there just a little ways.

MR. ZIGLER: What happened, Dr. Wallis --

and we have modeled this with the CFD and we can actually see it -- and the sense of what happens is that your flow stream now becomes basically slightly turbulent inside, and your flow stream in the hole, which before you had the hole, your fiber would have punched right through and then down on it.

Now you have the surface right behind the hole on it, so that flow stream is not perpendicular anymore. It hits it and it becomes turbulent, so you don't have the capability, whatever little fiber gets deposited on the surface of the neck and doesn't transpose down.

MR. SMITH: Okay. I have a few photos just showing some quantities of, you know, what came through and without the --

CHAIRMAN WALLIS: That's quantity, or that's just a sample?

MR. SMITH: No, this was the quantity.

CHAIRMAN WALLIS: That's the quantity.

MR. SMITH: Yes.

CHAIRMAN WALLIS: So we should look at the quantities and compare them here.

MR. SMITH: Yes. Yes. This is just a quantity. This is before and after. It does a pretty nice job. And the big thing is --

CHAIRMAN WALLIS: But the engineering question is: can you predict it?

MR. SMITH: You --

CHAIRMAN WALLIS: How much do you need to catch before there's a problem downstream? And all those kinds of questions.

MR. SMITH: We're still working with fuel lenders on determining what the limitation is downstream. And the thing to note is that this stuff is more powdery form. It's more closer to that of a particulate versus that of a --

CHAIRMAN WALLIS: But the screens that you're installing in plants have this bypass eliminator in them?

MR. SMITH: Yes, sir.

Again, we show some of the -- some of the material being strapped -- trapped on the surface of our knitted mesh material. The things -- this is some of our --

CHAIRMAN WALLIS: I would think that the chemical precipitants that they go through would actually make a nice, thin bed on that bypass eliminator.

MR. SMITH: Most all -- all particulate has passed right through this in the past, and I know

recently it was passing right through it. At one point it was --

CHAIRMAN WALLIS: Even after a bed begins to form on the bypass eliminator?

MR. SMITH: Oh, no, by itself.

MR. ZIGLER: By itself. There was a test that was conducted with the bypass eliminator and chemical precipitants --

MR. SMITH: Yes.

MR. ZIGLER: -- with the WCAP chemical precipitants by itself with no fiber, and there was no head loss increases.

MR. SMITH: Yes, it was passing right through. What we've seen -- this is, you know, some of our data at this point in time. We've seen standard perf plate, and the perf plate holes for our -- our strainers have been in the 3/32 size perforated plate hole with about a 27 to 30 percent open area.

We've got fibers ranging from around one micron to three -- excuse me, 1,000 microns to 3,000 micros in length. It's kind of a little ball, little puffs of stuff, and a little clumping going on. When we run with our secondary filter we get 80 to 90 percent, based upon our observation -- and this is using a microscopic evaluation. Less than five

microns, almost all are shorter than 1,00 microns, and it's displaying more of a particulate nature.

And we're using -- we're going after this as if it is particulate in nature, and many people are trying to approach this -- if it is particulate, it won't bridge, it will pass through and pass through downstream components that are -- we're concerned with the fiber actually getting in there and bridging.

And that I believe is the success path we're trying to get through here, is if you can show these things are short enough in length that they don't -- they transform from being a fiber material into that of a particulate material.

CHAIRMAN WALLIS: Those 3,000 microns, is that three millimeters?

MR. SMITH: Three millimeters, yes. I mean, they're short, eighth inch. And then we get it down -- we're running really short here, so -- and that's the end of our slide show.

MEMBER MAYNARD: Quickly going back to the module design, that feeds into a manifold. The water then goes from there to the sump?

MR. SMITH: Yes. Yes, sir.

MEMBER MAYNARD: And I'm assuming that that's a gravity flow, and these are put in in a way

where that offload --

MR. SMITH: We're all submerged at this point, and so it is fully submerged. It is not gravity, but you are all below the water level at this point, and it's the head of the water driving it, you know, to your pump located, you know, at a lower elevation. And so -- and then, we run through the calculations for internal losses and strainer head losses.

CHAIRMAN WALLIS: So this is a very interesting, descriptive presentation. It's not really an engineering presentation. I mean, you haven't said, "Here are the functional requirements and specifications for a particular plant. Here's the kind of debris that we handle. Here's the head loss tolerable. Here are the various conditions throughout the event, temperature and so on and so on. Here's the chemistry. Here is our design. And here is the proof that we're confident that it will work, because we have adequate data and we have adequate means of extrapolation and adequate means of predicting flow patterns in the plant, and so on."

There's a tremendous amount of stuff in the engineering of this that you haven't told us about at all.

MR. SMITH: When we were putting this presentation together, we asked, you know, what agenda to present. And we had an agenda from our past --

CHAIRMAN WALLIS: Yes, but I'm just wondering if it exists.

MR. SMITH: We have a lot of -- yes, we do -- go ahead, Gil.

MR. SMITH: In the end of everything, you're absolutely right, Dr. Wallis. We have what we call the strainer certification calculation. And this is where everything feeds in. This is where we come in with our composite curve that you saw on it, what we can then predict from that one using the 6224, which is pretty decent, incidentally, from a particulate standpoint, to extrapolate given parametrics of energetics and cotese failed, cogene, parametrics from CalSil, etcetera, etcetera, to provide the client with not a single data point but with a range of values that he can certify that that strainer will work over a large range of events.

CHAIRMAN WALLIS: So when I'm up there making a presentation to the Commission and some Commissioner says is it my opinion that you guys are really on top of the engineering and these things will work, I just have no -- nothing to say, because I

haven't seen anything. And just say they've described what they've been doing to me, but I have no idea whether it's going to work or not.

MR. SMITH: We have data that show it's working.

CHAIRMAN WALLIS: You have it, but I haven't seen it.

MR. ZIGLER: We would be glad to show that to you, but it just --

CHAIRMAN WALLIS: Maybe we need another meeting. Maybe we need a technical -- we need another technical meeting of some sort.

MR. SCOTT: Can I interject something? Mike Scott, NRC staff. You all are -- as all of you are currently in progress on this, right, you have not identified the success path yet that gets you to the end result that he's asking for.

MR. SMITH: Not for every topic, that's correct. We're still wrestling with that.

MR. SCOTT: So had you been asked to come in and provide that solution path, you're not prepared to do it yet, and I'm assuming nobody is yet. We're still working on this and are going to be for sometime yet in the future.

MR. SMITH: We have partials and pieces,

you know. We tried --

MR. SCOTT: Right.

MR. SMITH: -- to get through, you know, the classical testing of head lossing -- head loss testing, but to say we've bounded everything here, no.

CHAIRMAN WALLIS: We are usually asked for our judgment on things and whether things are going the right way and are you on the right track, and are you solving the problem, and so on. And I can say, yes, this description of stuff looks very interesting. I mean, you're doing stuff which sounds as if it's relevant. But I can't say much beyond that, because I haven't seen technical results from it.

MR. SCOTT: And the staff is not ready to reach a conclusion yet as to whether this will pan out without an additional set of actions to be taken. It's going to likely be iterative. And so, you know, six months, a year from now, we're obviously going to have a much better idea as to what's needed. But it's --

CHAIRMAN WALLIS: Everybody is going to be iterative on these chemical effects, because they've been showing more clogging than was desirable.

MR. ZIGLER: I go back to my opening slide, Dr. Wallis. Okay? We are looking at every

single step along the way --

CHAIRMAN WALLIS: I understand that.

MR. ZIGLER: -- and we -- when we stumble, we go back. And as I mentioned before, when we're talking about the chemical issue over here we're stumbling right down here. So we're now going back to debris generation and doing chemical debris generation, which is something which we haven't done before.

CHAIRMAN WALLIS: This is your plan of campaign. But until you actually fight the battle, we don't know if it's going to work.

MR. ZIGLER: Absolutely. Eventually we'll -- going through those do loops many times we'll eventually --

CHAIRMAN WALLIS: I understand that.

MR. ZIGLER: -- come down over here.

CHAIRMAN WALLIS: Right. I understand that.

MR. SMITH: Yes, and we've gone through those do loops with several types of classical insulation debris that many clients cannot -- you know, the strainer system could not tolerate it. And in many cases, they have gone -- had to go back and remove certain types of insulation material in their

plant. So we've gone through this do loop on a couple issues already.

MR. ZIGLER: Whether it's reducing debris, putting in debris interceptors, etcetera, etcetera, etcetera. But we have had campaigns, but the war is not yet finished.

MR. SMITH: Right. We've had little battles, but --

MR. CHOROMOKOS: One last thing. I mean, we came here with the intent of informing you of the activities we're doing to address it. We didn't come here with all of the addresses.

CHAIRMAN WALLIS: I understand that.

MR. BUTLER: Dr. Wallis, I'd also like to point out that some of the details that you're looking for are really the licensee's details. Intercon and the other strainer vendors are contractors to the licensees. If you're looking for that detail, we really have to pursue getting the plants themselves to present with their contractors.

MR. SCOTT: But not at this stage. It's still premature for that.

MR. BUTLER: Correct.

MR. SCOTT: Because the battle is still being fought, as was said.

CHAIRMAN WALLIS: Okay. Well, maybe we can ask the staff when they get up there how far along they think things have come.

Do we have any more questions? I notice it's time for our break. Ready to move on, have a break? Okay.

MR. ZIGLER: And, you know, if you're ever interested in seeing some of those tests, you're welcome to participate.

MR. SMITH: Yes. We have several tests scheduled for this fall, and so you all are welcome to --

MR. CARUSO: Is the staff observing your chemical effects testing?

MR. SMITH: They just did this past week.

MR. ZIGLER: Thursday and Friday they were there.

MR. SMITH: Yes.

CHAIRMAN WALLIS: Okay. Well, Gil, Aaron, Rob, thank you very much. We will take a break. We'll take a break until 10 minutes to 11:00.

(Whereupon, the proceedings in the foregoing matter went off the record at 10:34 a.m. and went back on the record at 10:53 a.m.)

CHAIRMAN WALLIS: Okay. Please come back into session. Apparently we gained about an hour on the previous presentation. Maybe we need to -- maybe they can come back and give us data, then, in that case.

We're looking forward to a presentation from AREVA on this same topic. You have two hours scheduled, but we'll see how it goes. We'll take a break for lunch, if you need that much time.

MR. WILLIAMS: Okay.

CHAIRMAN WALLIS: Probably will. So we'll probably interrupt your presentation. Maybe if we get to a good point we'll -- you can point out to me or I'll point out to you that we should take a break for lunch. Go ahead.

MR. WILLIAMS: My name is Lee Williams. I am the General Manager of Plant Engineering for AREVA in the U.S. AREVA, for those that don't know, is the former Framatome ANP.

Appreciate the opportunity to be here this morning. I want to introduce my team. We have a team put together including ourselves, and we do primarily engineering. Alden Laboratory, represented by Dr. Stu Cain on my left, is where we do the testing, and also on my left, Jim Bleigh from Performance Contracting,

who does the strainer design itself and the fabrication of the strainers. And we'll show you some of those pictures as we go forward.

Also with me is Ken Greenwood, who is my technical lead in AREVA. So we'll be sharing in this presentation.

Just a couple of opening remarks. This team that is put together -- we have done work -- we were in this issue back in the BWR days back in the middle '90s. And we've been heavily involved in the upfront engineering for the PWRs as the previous presentation talked about the generation, transport, all facets of this, all the way through strainer design and now up to installation and subsequent followup testing.

One thing I want to point out is that, you know, as we went forward many of the clients that we had wanted to move forward to -- in order to meet the NRC dates. So as things were developing, we were developing test protocols and, as you will see, our test protocol in some cases has evolved based on our own client input, the NRC interaction which we've had quite a bit of during the process, and our own experiences and our own discoveries.

CHAIRMAN WALLIS: Excuse me. Because of

the Framatome connection the French have had a lot of experience with putting in bigger screens. Does this give you a leg up in the work? Were you able to rely on data and the design methods, and so on, from France?

MR. WILLIAMS: Well, I mean, even at this time EDF is actually increasing their screen sizes as -- you know, usually it's the same kind of methodology criteria that's being used in the U.S. We didn't really have a lot --

CHAIRMAN WALLIS: I think they started it before we did, though, didn't they?

MR. WILLIAMS: It's very much -- about a year earlier I think.

CHAIRMAN WALLIS: So you should have a leg up on the competition here.

MR. WILLIAMS: Well, sometimes the information is not directly applicable, as you well know from France to the U.S. We did have some information, but nothing that really I think -- actually, as we got into it, I think we ended up getting more information rather than direction, to be perfectly honest with you.

And I think one of the things we want to emphasize here as before -- the resolution of this

issue needs to be addressed from a big picture standpoint. It's got to be looked at in the conservatisms as there are assumptions being made. The testing approaches that are being used, the size of screens that are being installed, very much like we did with the boilers, and you'll see some references to some protocol and decisions we made that basically grew out of what was done and acceptable for the BWRs.

One of the things we want to note here just very quickly, this is for the benefit of our clients that we -- they were a little concerned about the -- you know, we are representing a series of clients of about 15 units. This information is submitted for the information for the ACRS and the NRC staff, but specific information on a plant basis really is the responsibility of the licensee.

General topics -- and I don't know -- I apologize up front, we -- we have set up our presentation, Dr. Wallis, very much like the previous one.

CHAIRMAN WALLIS: Well, let's go back to the previous questions here. You say that it's all the responsibility of the licensees to make their case, which is true. But presumably you've set up an engineering base which enables them to make their

case.

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

CHAIRMAN WALLIS: That base has to be validated and accepted and believed and so on. Once that's done, then maybe it's easy for the licensees, or much easier.

MR. WILLIAMS: Well, you have to understand there is many aspects of this that come into play. And not one vendor for one plant is really handling each aspect. In other words, what I mean was you have one group that did generation transport, somebody else may be doing the screen design and installation, somebody else may be doing bypass. So it -- there is --

CHAIRMAN WALLIS: There are different consultants or vendors or something like --

MR. WILLIAMS: Yes, absolutely.

MR. GREENWOOD: I think it's important -- this is Ken Greenwood, AREVA. It's important to note I think this -- the purpose of this, too, is more directed towards the data tables later in the presentation.

MR. WILLIAMS: As I started to say, we have set this up as a -- to focus more on the testing

with some overall general information previous to the -- similiar to the previous presentation, so your comment about lack of data may obviously apply to us also.

CHAIRMAN WALLIS: Well, there's going to be a prize for whoever comes up with some data in these presentations.

MR. WILLIAMS: Well, we have some data and a couple of tables we'll walk you through. We'll go from there.

Starting off with a facilities overview for the test, Stu Cain will walk us through that.

MR. CAIN: Stu Cain, Alban Research Laboratory. I'll just walk you through our test setup very briefly. The flume setup that we have, you can see on the right-hand side here a little bit better in your handout. We have a flume that's 2.25 feet wide, 3-1/4 feet tall by almost 21 feet long. We have a flow capacity that is a calibrated flow capacity of 10 to 120 gpm, and our pump is capable to a maximum of 30 feet of head. So we can go up to relatively high heads.

We have return flow options for this loop. A couple different options exist. We can return flow directly to the upstream end of the flume. We can

also divert the flow to overhead spray nozzles. Now, those overhead spray nozzles were designed to provide agitation to the flume, provide kinetic energy to suspend the material in the flume.

CHAIRMAN WALLIS: And they don't get clogged up by bypass debris?

MR. CAIN: They do not, no. No. We have a sufficiently large hole diameter on the nozzle. We can change nozzle diameters. We can change the vertical fall height of the water. We can also submerge the nozzles to achieve different energy levels.

CHAIRMAN WALLIS: Pretty cold water for a sump.

MR. CAIN: Well, it's actually city water. And if you saw our laboratory, you would realize there's quite a stretch underground that the water has to flow through to get to our facility.

Strainer pressure differentials were in the range of about .02 feet to 12 feet, and, as you said, the water temperature was 40 to 70 degrees Fahrenheit.

Go ahead, Lee.

CHAIRMAN WALLIS: And when you do tests at -- over this range of temperatures and then you apply

them to a sump at 200 and something, now there has to be an equation or something which tells you how do you take account of the changes in viscosity and --

MR. CAIN: Yes.

CHAIRMAN WALLIS: So you use supply design equations, then?

MR. CAIN: Yes. This is a picture of the test facility. I'll just point out a few things on this slide. This is the flume here. It's elevated because we can run a couple different types of configurations. We have a pit configuration or a depressed sump configuration here.

We can mount off the back wall. We can also mount vertically in the system. These are the overhead spray nozzles. This is the overhead spray manifold. This is the return piping. So we can send it through a couple of different orifice plates here for flow measurement back up to the spray nozzles or to the front end of the flume.

CHAIRMAN WALLIS: These are all two by fours that are holding it up?

MR. CAIN: It is, yes. Structurally designed, of course.

MR. WILLIAMS: And we've had loading conditions where we've had to reinforce the --

CHAIRMAN WALLIS: So you've gone away from angle iron and all those kind of things. This seems to be going back to the '30s or something.

MR. CAIN: Well, this flume actually is a fairly old facility. It was pre-BWR testing. And when we did the pit configuration we needed to raise it up. It was on the floor originally, on cinderblocks. Right here you can see -- and we'll show pictures later on -- this is the location of our bypass sampling. We have three isokinetic bypass sampling ports where we can pull off bypass samples.

MR. WILLIAMS: One of the original thoughts in building the flume, Dr. Wallis, was that we were looking at the differences between BWRs and PWRs, and one of the significant things we saw in many of the plant configurations, that around the area of the sump was a fairly quiet pool because of the, you know, flows. And, therefore -- and you'll see the range of flows that we're dealing with all the way from 2,000 gpm to 19,000 gpm at the onset of recirc.

One of the original thoughts was, how much credit can we take for the settling in and around the closed-in area of the sump itself? And so our initial test we had -- we were moving the -- started with the debris somewhat spread across there, but as we got

input, not only from the NRC staff but looking at the conservatisms with our client, we later -- the latest test had the debris all moved up towards the strainer itself as well as the -- as Stu said, the agitation of those downward jets keeping things suspended.

So we -- the test methodology evolved, because there really wasn't a standard protocol established similar to what the BWRs had. So we -- we evolved it and got better as we learned.

MR. CAIN: Just a couple of photographs of strainer mountings in the flume. This is a pit configuration, so this is a single module, and this is -- you're looking at in a plan view. This is the pit in here, and it's sitting down inside the pit.

MR. WILLIAMS: This is the floor level of the flume itself, and this is to simulate the closed-in edges of a pit configuration. You can see that the -- Jim, you might want to take a minute and describe what the module is, so Dr. Wallis has an understanding of that.

MR. BLEIGH: Basically, we make a stacked disk strainer, which is a series of nominally half-inch thick disks with a face plate on both faces, a disk rim around the perimeter. All of that is perforated plate. They are separated by what we call

gap rims, which is also perforated plate, and the gap rim is a larger diameter than the core tube that is inside.

So when you see those four bolts on the outside of those four bolts would be a gap rim, but on the inside of those four bolts on the inside of this cross and collar here is where a pipe is and a core tube. And the core tube has holes in it of different sizes that vary from the section end to the far end, and the purpose of the flow control holes is to create uniform flow along the axial length of all of our strainers, so that the furthest disk from the suction line is going to draw the same amount of water as the nearest disk.

CHAIRMAN WALLIS: At least before it gets debris on it, yes.

MR. BLEIGH: Correct. You know? But that would assume non-uniform debris loading. If we have uniform flow to all surface areas, we're assuming that debris is going to collect, unless it's from a single direction, in a uniform manner.

CHAIRMAN WALLIS: So these are stacked disks. So a lot of the area is between these layers.

MR. BLEIGH: That is correct.

CHAIRMAN WALLIS: And if it fills up with

debris in there, then your approach velocity perhaps should be around the whole box rather than --

MR. BLEIGH: Right.

CHAIRMAN WALLIS: -- based on the entire area.

MR. BLEIGH: That's correct. And we're testing these in both low fiber conditions where the gaps are not filled in. We're also testing them in completely buried submerged --

CHAIRMAN WALLIS: You get them like the ones we saw earlier this morning, where --

MR. BLEIGH: Absolutely.

CHAIRMAN WALLIS: -- there's several feet of fiber maybe above the whole thing.

MR. BLEIGH: Oh, absolutely.

CHAIRMAN WALLIS: All right.

MR. BLEIGH: And I think we have pictures later in the presentation where we buried the strainer with mixed debris of fibers and particulates.

MR. WILLIAMS: But to make a point that you're right about the circumscribed flow here. That was one of the areas -- things that we did going forward, and the first plants we tested were extreme low fiber plants, really circumscribed area, then becoming neglected because you had no material to fill

in the gaps. But as we got higher fiber plants, then we evolved to running a suite of flow rates, including the circumscribed flow area.

MR. BLEIGH: And one of the interesting things when we started the testing program that was very limiting in terms of the size of prototype modules we use is that for high fiber plants -- and you might recall a year and a half ago they talked about 50 pickup loads of debris going to a screen, if I make the screen too large for the physical size of this flume, the entire flume is filled with debris.

So there is a limit in terms of how large a prototype can be tested based on the design basis that we're using. And so, you know, there was a number of variables that we had to balance to decide what size screen are we going to use.

MR. WILLIAMS: And as Stu was saying, this is giving you -- is the flexibility that we built into the flume.

MR. BLEIGH: And, again, the flume is designed to accommodate all of the plant configurations, whether it be a horizontal strainer, a vertical strainer that's in a pit, or a vertical strainer that's actually sitting on the floor. So in this flume we're able to actually test all three

configurations.

CHAIRMAN WALLIS: Well, if it works with this -- when it's buried in fibers, then, really, the details of this are less -- become less important --

MR. BLEIGH: That's correct.

CHAIRMAN WALLIS: -- as it's flowed through all that fiber that's --

MR. BLEIGH: That's correct.

CHAIRMAN WALLIS: -- covering everything. You have all this area. Is that really because of those thin bed effects, or something? Or why do you need all of the area?

MR. BLEIGH: Absolutely. The --

CHAIRMAN WALLIS: You only need it when you have the thin layers on it, right? And chemical effects or something. But once you're into the submerged thing, it's a completely different regime.

MR. BLEIGH: Yes, that's correct. It's a completely different --

CHAIRMAN WALLIS: You wouldn't need to have all of this area, presumably.

MR. WILLIAMS: I think we have to go back to the evolution of how decisions were being made as we went forward to start the test program. In many of the plants, they look at not only -- you look at a

calculation of 6224 based on their debris loads, but they also looked at space available.

Several of our plants said basically, "Here's the footprint. Fill the space with as much surface area as you can get, and we will basically back our way into the solution."

CHAIRMAN WALLIS: So when you say 7,000 square foot of surface area, that's all the holes and all these plates. How does that compare with the sort of superficial area of the box?

MR. BLEIGH: It depends on the plant design, because the larger the disk design, then the difference in that ratio -- if it's not a large --

CHAIRMAN WALLIS: It must be something like an order of magnitude, isn't it?

MR. BLEIGH: No, it's not that bad.

CHAIRMAN WALLIS: It's not that bad?

MR. BLEIGH: No, it's like maybe twice.

CHAIRMAN WALLIS: Only that?

MR. BLEIGH: Right. I mean, you lose two or three times. Again, it depends on the plant arrangement.

MR. WILLIAMS: And it depends on the -- in some plants we have an array arrangement, which is over the sump pit itself. And then some plants, as

you -- similar to what you saw earlier, that had the -- had a small area, and didn't have a sump pit at all, and then we ran the strainers out around the crane wall.

MR. BLEIGH: And as was mentioned in the previous discussion, the flow ratio of these screens are extremely slow. I mean, it's almost stagnant water, you know, in and around the screen areas. And so you don't get compression of the debris bed, you know, near the screens.

MR. GREENWOOD: Okay. This slide here shows what Jim is mentioned. Ken Greenwood, AREVA. The plant design flow rates that we're dealing with covers the -- illustrates the large disparity of plant conditions that we had to deal with.

Plant design flow rates, as Lee had mentioned, from 2,000 to almost 20,000 gpm. Approach velocities -- excuse me, the screen approach velocities were very low based on the large square footage of the new plant screens. Again, you can see the large range there. And the hole diameters, just to make things consistent, roughly 3/64 to 3/32.

The testing parameters, which represent the prototypes which were tested, flow rates were scaled down based on the screen surface area, show 15

to 120 gpm, and the screen approach velocities here are the same. Those were the intent of the scaling was to -- to maintain the screen approach velocity.

So the area was based on debris loads and other physical configurations, and then the flow rates were determined based on maintaining consistent approach velocities.

CHAIRMAN WALLIS: You are testing essentially one module out of many modules, is that what you're doing?

MR. GREENWOOD: That's correct.

MR. WILLIAMS: What would be done, Dr. Wallis, is that we would come up with a preliminary screen size that would go in the plant. And based on that surface area and the plant flow rates at the onset of recirc, the maximum flow rates, we would establish a screen approach velocity, and then use that as a scaling factor, and have that same approach velocity in the flume test setup.

MR. GREENWOOD: Just one last thing on that. The strainer hole diameters were also maintained to the prototypes.

MR. WILLIAMS: That's correct.

MR. GREENWOOD: This is the list of licensees that we're working with, the current status.

We've got six units fabricated and delivered. Nine units are in fabrication now, and we actually have one plant installed. And you'll see some pictures of that later in the presentation.

MR. WILLIAMS: And we actually began testing -- because of the schedule that many of these plants had, some of these were starting to install as early as this spring, with several of them this fall. We started the test setup in late October/November last year. Actually, in September.

MR. GREENWOOD: These are some of the parameters that we found that affected the head loss during the testing. I think you've heard about some of this before. One of the things that maybe you haven't heard was the overhead nozzles. Again, here, this was our intent to keep the debris in suspension as much as possible without introducing enough energy to actually dislodge debris from the strainers themselves.

CHAIRMAN WALLIS: When it says "debris mix," it's also how you put it in, isn't it? I mean --

MR. GREENWOOD: Yes.

CHAIRMAN WALLIS: -- and the order in which you put it in, and things like that, can make a

difference.

MR. GREENWOOD: Yes. We have a slide to address that. Next one?

Some of the observations early on -- the tests included some of the miscellaneous type debris of tags and labels, RMI, paint chips.

CHAIRMAN WALLIS: Where do they go?

MR. GREENWOOD: They just settle to the floor.

CHAIRMAN WALLIS: Settle to the floor, okay.

MR. GREENWOOD: Yes.

MR. BLEIGH: And they don't appear to have width velocity to come up. They just go down and stay down.

MR. GREENWOOD: Even when dumped practically on top of the strainer, it just passes by to --

MR. WILLIAMS: I'll show you a couple of pictures. We actually forced -- we did some testing on paint chips in a low fiber condition, and the only way we could get it to the strainer is actually physically dump it and then shovel it onto the strainer. It would not pick it up.

MR. GREENWOOD: The 6224 correlation was

a bounding -- in many cases used some of the initial designs, and testing ones corrected for temperature came in well below that.

CHAIRMAN WALLIS: This is because of non-uniform distribution, presumably, rather than because the correlation is way off? Or is the correlation way off --

MR. WILLIAMS: I think it is the correlation that is developed based on flat plate information, and now you've got complexity, a lot of hydraulics going on in and around the strainer itself that doesn't --

CHAIRMAN WALLIS: I think it must be non-uniform distribution, then, because if you have this stuff uniformly distributed -- these are almost flat plates you have. They're disks. They're almost --

MR. GREENWOOD: Correct. I think the difference is 6224 wasn't a vertical loop. Here you've got the effects of gravity which can keep debris away.

CHAIRMAN WALLIS: You'd expect it to be reasonably uniform. You've probably got some flowthrough or whatever you call it -- you know, bypass the holes through the fiber bed and stuff and --

MR. BLEIGH: But in many of our thin fiber bed tests, the screen is completely covered. We have, you know, not perfect, but we have coverage of fibers everywhere.

CHAIRMAN WALLIS: But you would expect this correlation to do not too badly.

MR. BLEIGH: I think it's because of the low flow rates and the fibers just not compressing against the screen. It's at the screen, but it's not compressing.

MR. GREENWOOD: We're at the very low end of the 6224 correlation.

CHAIRMAN WALLIS: They have predictions for no compression, too. It's probably in the laminar region, isn't it? It's very, very --

MR. GREENWOOD: Very much so.

CHAIRMAN WALLIS: So it should be linear. It should be very straightforward.

MR. GREENWOOD: And the other thing is that the amount of debris that you would put in for the correlation would assume 100 percent accumulation. In this case we would have much of the debris drop to the floor below the strainer.

CHAIRMAN WALLIS: You'll have to have Gil look at why the NUREG didn't work, since he's the

first author on it.

MR. WILLIAMS: It works.

MR. GREENWOOD: And one last slide for me is the geometry. This is some things that Lee had alluded to before. Our testing protocol evolved over the course of testing. You mentioned the debris placement, use of overhead nozzles, which nozzles to use and at what elevation to place the discharge, again depended on -- a lot of that came from experience as well as observations from the staff and clients. But in the end, our maximum head losses seem to be fairly consistent.

MR. WILLIAMS: We actually did some sensitivities utilizing the change in debris placement and flow rates and a couple of series of tests. We found we got fairly consistent maximum head losses, but as you might expect debris placement will obviously have an effect on the time it took to get to that maximum head loss.

CHAIRMAN WALLIS: So what are you going to give the licensee for a correlation? This NUREG-1 is very conservative. Do you have an AREVA correlation or something? What are you going to give the licensee to use as a design tool?

MR. BLEIGH: We're giving them the

measured debris head loss, and we're showing how that correlates to a NUREG calculation. And it's really up to the licensee to decide, you know, how they want to use the correlation and the two data points.

CHAIRMAN WALLIS: Is it far from the correlation?

MR. BLEIGH: In some cases it is.

CHAIRMAN WALLIS: So they may wish to use the data rather than the correlation.

MR. BLEIGH: That's --

CHAIRMAN WALLIS: Or will you develop a new correlation that goes through the data or something?

MR. BLEIGH: I think that many of the licensees are looking at the NUREG calculation as the bounding condition for the plant. And so the testing becomes confirmation that the calculation using NUREG is bounding and conservative.

CHAIRMAN WALLIS: And the interesting situation will be when they find that the conservative one gives them too much pressure drop.

MR. BLEIGH: No, it is not.

CHAIRMAN WALLIS: It doesn't.

MR. GREENWOOD: I mean, as far as the margin is concerned, we're given -- our clients have

given us -- you're allowed so many feet without getting into the details of --

CHAIRMAN WALLIS: Based on the NUREG.

MR. GREENWOOD: No, no, based on the NPSH calculations.

CHAIRMAN WALLIS: Yes, but then whether or not it's there is based on the NUREG calculation and -- as I understand it, and you're showing that your data all lie below it. Therefore, this is a --

MR. BLEIGH: As an example, if we have two feet from the client, and we add together clean strainer head loss component to the debris head loss calculation using NUREG-6224, maybe that's 1.5 feet.

CHAIRMAN WALLIS: But you measure as .2 feet or --

MR. BLEIGH: And what we measure might be .5 or 1 foot.

CHAIRMAN WALLIS: But the acceptability is based on the NUREG. Acceptability of the design is based on the NUREG, and you are simply showing that it's conservative, it sounds like.

MR. BLEIGH: The testing is showing that the NUREG calculation is conservative.

MR. WILLIAMS: But you've got to be 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

the test. And we would then do an evaluation to get the corresponding viscosities, and the perfect temperatures at the plant were outlined to us.

Again, many of these items that we've done is completely consistent with how the BWR strainers were tested and qualified.

I mentioned earlier that the scale fraction forward of the test debris and test flow was a function of the ratio of the strainer surface area to the plant strainer surface area, where we would maintain based on the flow rates in the flume a consistent strainer flow velocity.

We also noted earlier we did some sensitivity tests. Many of the tests had actually used circumscribed flow area, but we did sensitivities at higher flow rates also, just to determine what some of the varying conditions would be.

Debris preparation -- this simply has some pictures of, as you can see, the quantities of debris we're dealing with. We weighed the debris dry. All the insulation, both fibrous and RMI, was chopped, cut, segregated, you know, in many different ways. In many cases we even used -- put some through a food processor.

Water was added. We mechanically mixed,

as you can see over on -- over on the right-hand side, and we'll talk a little bit about some of the surrogate material we utilized as was previous -- in the previous presentation. We were very careful about that based on size, density, and, you know, again, precedent with some of the other BWR evaluations.

One in particular was a substitute for the zinc primer, because we were testing at Alden Laboratories in Massachusetts where the EPA has deemed zinc a hazardous material, and it was extraordinarily difficult to try to dispose of. So we came up with a tin powder surrogate based on an evaluation between that and the zinc primer.

Sequencing -- as you mentioned, it is an important aspect. We came up -- again, this evolved over some period of time in terms of the order of the debris. One of the things we didn't want to do is put the RMI -- put the fibers in and then throw the RMI on top, and that basically would then trap a whole lot of fibers that couldn't -- that wouldn't have the opportunity to make it to the screen.

So what we came up with was this type of just a fundamental order, we would mix these constituents separately and thoroughly with mechanical mixing in drums, and then add the material. And as

you'll see from our data chart, as I said, the first couple of tests we spread it out fairly uniformly, and then subsequent tests we either put it between one and three feet in front of the strainer itself or actually on the strainer in many cases.

But we put the RMI in, put all of the particulates in separately, and even if you put it near the screen, as you know the particulates will tend to scatter. Fibrous material would be next, and the latent fiber would be added, and then what we were using for chemical precipitants -- we'll talk about it a little bit later, but we -- in the beginning of the test, while the WCAP was being developed, we were utilizing manufactured chemical materials based on the ICET outputs. And we subsequently evolved to balancing those against the WCAP methodology, and we'll talk more in detail about what's going on there.

CHAIRMAN WALLIS: Well, suppose you're doing particulate on fibers. You throw in all the particulates, and you're running the test, and it's going through the --

MR. WILLIAMS: At this point, when we first add the test it is not running.

CHAIRMAN WALLIS: Not going through the loop yet.

MR. WILLIAMS: It's not going through the loop. We don't have --

CHAIRMAN WALLIS: So all this stuff is put in before you -- before you start the pump? It's just stirred up in there?

MR. WILLIAMS: Right. We layered in there, and then mechanically agitated it and --

CHAIRMAN WALLIS: Okay. Because there's another sequence where you put in the particulates and run the thing around. And then, you put in fiber progressively and build up a bed, and then it catches the particulates. It all takes time. You haven't done that sort of sequencing where you're running the loop while you're putting the stuff in?

MR. WILLIAMS: We did -- you know, we did --

MR. BLEIGH: Actually, it has been done both ways, but we didn't see significant differences in results.

MR. WILLIAMS: Because, you know, the PNNL people had huge differences depending on the order in which they put stuff in.

MR. BLEIGH: The order has an effect. We -- you know, what we see, though, Dr. Wallis, is once we put this material in, that obviously the

particulate gets there -- if the material is, you know, right in the vicinity of the screen. And then, the -- you'd then build up a debris bed gradually as you continue to run the test.

So, in essence, though, we didn't do it in a separate condition, because to be honest with you we had so many constituents of material to add in here -- in many of these tests there was -- you saw some of those barrels. There was sometimes 15 of those barrels of different materials, particulates and different fiber loadings, that had to be added.

MR. BLEIGH: I also think sequencing would make a difference in a vertical pipe test as opposed to an actual or more representative arrangement.

MR. WILLIAMS: What you see here is, this was a very high fiber test, and you'll see -- this is the overhead sprays. There's a mechanical mixing of the debris, and you can see just huge amounts of debris in some cases that, again, resulted from the conservative debris generation during transport.

CHAIRMAN WALLIS: Now, the sump isn't agitated like this in a plant. The sump is not agitated like this in a plant.

MR. BLEIGH: No, this is -- occurs just prior to starting recirculation.

CHAIRMAN WALLIS: So something is different between this and what happens in the plant.

MR. WILLIAMS: Well, what we tried to simulate, we knew in many cases the material had to take a very torturous path to get to the sump, and we knew there would be some -- there would be mixing and tumbling and just a grouping of the materials before it got to the sump, because it -- the material was not right at the sump, you know, independently. So we knew there was some mixing going on with the -- based on the CFD analysis we ran in several units.

MR. GREENWOOD: One of the things that we did there, too, was -- is that because you put in the debris in sequence, by the time you got to the last item you already had a large amount of the material settling, because the pumps were not running. So an attempt just prior to starting those pumps to lift the fibers and things up to make them more susceptible to being captured by the strainer itself, was one of the main reasons for this mixing.

MR. WILLIAMS: And, again, the debris introduction, we only use this protocol for the 3 to 15 feet in the first test series. Afterwards we went within three feet of the strainer. And actually, in the first test series on the 3 to 15 we did some

sensitivity tests where we shoveled everything that was in the flume on top of the strainer at the end of the test and doubled the flow to see what effect we would get.

So we did some -- you know, we tried to do some bounding and conservative assumptions while still maintaining, you know, the aspects of realistic behavior of what was in the plan. And, again, the overhead nozzles in the later tests, one of the things we actually submerged the nozzles, the nozzles were originally put in in order to try to simulate a near break energy in put into the area around the strainer.

But one of the things we had to be careful about, as you heard in the previous presentation there's a balance between the amount of energy you impart to keep the material suspended as best you can, and if you go too high then you have a possibility of actually dislodging the debris bed on the strainer itself. So we were balancing those two aspects of it.

This gives you a little bit of an idea of the types and differences of material. This is in a -- one of the strainers in a pit configuration. We've drained down after the test, and you can see this is RMI that has gotten there. These are tags and labels. This is fibers. This is some -- this is MIN-K, if I'm

not mistaken.

MR. GREENWOOD: The dark material is the coating surrogate.

MR. WILLIAMS: The coating surrogate, thank you. So you can see there's -- but in the area, even after drain down, there is -- you can see the gravity just pulls the material away from it.

CHAIRMAN WALLIS: There seems to be clumps of stuff hanging off the edge of the --

MR. WILLIAMS: There are. I mean, and it does clump -- it tends to clump back up even after you mechanically shred it up and put it in water. Then, as it collects on the screen, it will tend to clump back up.

MR. CAIN: And as we draw down the water level, you can see as the water level is drawing down the material slumping off and agglomerating as the water level is brought down. So some of that -- and it's catching on the support --

CHAIRMAN WALLIS: You're trying to clump off some of this stuff, because it's gathered on the outside walls, will fall down.

MR. CAIN: Right. This isn't indicative of what the strainer would look like under the operating condition. So it would be fully inundated.

MR. WILLIAMS: And this is in the operating condition. Again, this was -- this is the kind of materials that -- and quantity of materials. This whole pit is completely full. The strainer is down in this area. And one of the things that, you know, caused us some problems from a visual standpoint is that once you put in some of these particulate materials that the water became so cloudy you didn't have a picture.

In this case, there is so much material covering the strainer that you can't get a visualization. But this does give you an idea. All of the material is basically right here. What is back in this area has basically drifted there because there was no driving force to keep it piled up in this area.

CHAIRMAN WALLIS: What's your bed thickness? Your bed thickness here is several feet, presumably, and it has to filter through all that stuff to get to the --

MR. WILLIAMS: It had to be, yes.

MR. BLEIGH: It's anywhere from several inches above the strainer, because submergings is usually two or three inches, and at least it started recirculation. And then, depending on whether you're in front or behind the strainer or around the

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

CHAIRMAN WALLIS: So we might as well design for flow through porous medium? And the limiting factor here is presumably the flow through all that stuff lying on top of the strainer rather than --

MR. BLEIGH: Right.

CHAIRMAN WALLIS: -- the strainer itself.

MR. CAIN: And the higher the velocity, some more of that would compress and the higher the head loss you'd expect.

CHAIRMAN WALLIS: But it doesn't compress at all in your case, does it?

MR. CAIN: No. Our approach velocities are so low --

MR. BLEIGH: By controlling the flow in every module, you know, we're not forcing debris to compress against the shell of the screens and then force that debris bed to become more blocking. You know, experimentally, it would appear that there is a target or a trigger point, and it can be different for different kinds of debris mixes, where when you finally start that phenomena of compressing the debris bed it feeds itself, because once you start compressing it, then it has to suck more and then that

forces more compression.

So the key is to keep whatever that trigger point is of velocity at -- below a certain point so the debris approaches the screen but never really compresses it into --

CHAIRMAN WALLIS: I think it is stable. You could presumably envisage something where as it begins to compress the pressure drop goes up. It keeps on compressing, and eventually goes -- you know, it -- that would be an unstable bed, I would say.

MR. BLEIGH: Right.

CHAIRMAN WALLIS: I don't think the characteristics of fiberglass are like that. And usually, you increase the flow, it compresses a bit more.

MR. BLEIGH: Right. And it has a compression factor --

MR. WILLIAMS: That's what -- that's exactly what we've seen. It's very interesting, because in many of the plants we have these very high fiber conditions, but we would run, you know, the thin bed type test with much lower fiber. And as consistent with the theory we saw and practice we saw in the BWRs, we would get much higher head losses with just the thin bed and the full particulate load than

we would in a condition like this. In many cases, a condition like this gave you, you know, half a foot or less of head loss.

CHAIRMAN WALLIS: Better to have the particulate spread throughout a big --

MR. BLEIGH: Exactly.

CHAIRMAN WALLIS: -- bed than it is --

MR. BLEIGH: Normally speaking, the head losses are better with a high fiber load than --

CHAIRMAN WALLIS: And as long as you don't somehow get the fibers of particulates in first or something, so they make their thin bed right on the screen.

MR. BLEIGH: But it appears that because of the low compression bed that particulates, because, again, we're using very small micron size particles to represent the particulates, they are finding flow paths very easily through a non-compressed fiber bed. And so they're in recirculation.

CHAIRMAN WALLIS: I guess the grounds for concern would be something like this. If you build up your fibers, and then due to chemical effects which take some time you have some particulates or gels or something coming along later, which make a skin on top of this thing, which then really does compress it --

MR. BLEIGH: And I think that the key point there is, are the particulates in the form of small micron particles such as recirculating all of the time through this test anyway?

CHAIRMAN WALLIS: Going right through the fiberglass and everything.

MR. BLEIGH: It was just passing through. Or is it more like a gel or a gelatinous mass it is actually attaching to and staying on the surface. So the form of the particulate is going to make a difference.

CHAIRMAN WALLIS: Yes.

MR. WILLIAMS: This next photo, in one plant's condition, and consistent with the NEI guidance, if you have a very low fiber condition -- we had a couple of plants that had literally no fiber other than some small estimated latent fiber, so -- and they wanted to test a very high paint failure condition potential, so we came up with a method to establish paint chips, essentially developed a methodology to develop the chips themselves in different size ranges. But because there was no fiber we tested these in the flume near the strainer, just not enough vertical velocity component to get it to the strainer. So at the tail end of the test we

essentially shoveled everything on top of the strainer.

What you see here is the strainer is essentially in this area right here, completely buried in chips. And we really did not get substantial head losses at all, even in that condition.

CHAIRMAN WALLIS: That's because they are pretty stiff chips, and if they were very fluffy like leaves they would sort of layer, and then they might really block everything up. I think because the chips are hard --

MR. BLEIGH: They really are. They're not a very flexible chip.

MR. WILLIAMS: But certainly, fluid had a tortuous path, even though they -- even if they were hard because of the quantity they were talking about. It wasn't a very easy pathway to the section line.

This is some of the data. And one of the -- a couple of questions you may have here. The plant names -- basically, we go Plant A, B, and C. I'm sure that the plant clients themselves would offer which ones that they would -- which category they came into.

But one of the things I want to point out here on the test, you can see that we did a test series for each one of the plants, up to five test

series, and there are several reasons for that. In many cases, if it was high fiber, we were looking at low fiber conditions as well as high fiber.

In many cases, because of the variation in break locations, we had a couple different design-based loading conditions in terms of one would be particularly high in fiber, another would be particularly high in, let's say, coating load or something like that.

So we had several variations, and you can see from the plant under the flow rates, the gpm, the variations here, we made some -- also had some conditions where we would test small break LOCAs. Like in the -- in this condition, Plant B here, Test 5, you can see that the flow rate is about half of the first three tests. But that was because it was a small break LOCA condition, and we wanted to simulate that also, where they would have a lower flow rate demand on the ECCS but a different debris condition essentially estimated.

So what has this information here -- there's the design test flows, circumscribed test flows here, and which ones we ran those on. We gave a description of debris placement where it was. As you can see, it's all within three to five feet in

most cases. In some cases -- you'll see in the next one it's on top of the strainer.

Whether we used overhead nozzles. Over here is the screen areas that were actually estimated for the plant, and then the testing screen area in this column. Hole sizes varied from .095, as Ken said, to .045. And I'll go to the next one, which has -- this is the same chart with several more units listed here, so you can see the variations in screen sizes and hole sizes that we've tested.

This is a follow-on chart with, again, starting back with Plant A, B, and C. This gives you some head loss results at design flow rates, and then the head loss results at circumscribed flow rates, average test temperature, what termination criteria were utilized, and we also looked at percent change of head loss at termination as a -- one of the questions that we were working with the clients on as -- if you have a test termination criteria, which at some point you do, how do you take that data and necessarily extrapolate that if you're getting even small increases in head loss at the time of termination.

CHAIRMAN WALLIS: I'm looking at -- maybe it's the next slide. You've got Plant D. Debris placement is within three feet of the strainer.

Plant G it's on top of the strainer.

MR. WILLIAMS: Right.

CHAIRMAN WALLIS: But on H it's 3 to 15 feet upstream of the strainer. These are all different conditions. How is the NRC going to evaluate these tests when they're all different?

MR. WILLIAMS: Well, one of the things -- as I stated earlier, in the test -- I forget which slide you're on here. Which one? Next one?

CHAIRMAN WALLIS: Why are they different for different plants? I mean, the plants don't deposit debris on top of the strainer or within three feet or something.

MR. WILLIAMS: Well --

CHAIRMAN WALLIS: How do you pick that particular number there? I mean, why is Plant G different from D and H? And how do you pick 3 feet, 15 feet, 1 foot, on top of?

MR. WILLIAMS: Well, in my cases, as I said, there was an evolution where we started spreading debris out in the first series of tests. Those are very low fiber conditions, so it really didn't make much difference whether it was on top or near the strainer.

We had questions working with the staff as

to, well, are you really giving too much credit for gravity, because the material was settling too far away from the strainer. So we began to move, you know, testing material right at the strainer, and in some cases we'd have a client that said, "I don't want it on the -- you know, in front of the strainer. I want it directly on top of the strainer." So that may have been a preference for them to add even more conservatism.

CHAIRMAN WALLIS: Well, a question I have, how do you take the results, then, and use them in the plant? I mean --

MR. WILLIAMS: Well, that's something we would be working with particular clients, how they take this data and apply the data --

CHAIRMAN WALLIS: Are the 15 feet data better than the 3 feet data, better than the 1 feet, or are they all the same, it doesn't make any difference?

MR. WILLIAMS: Well, that's the thing -- I mentioned we did some sensitivities in terms of maximum head loss to determine how much effect you would have, and what we saw was a very consistent total maximum head loss under different conditions. Just the timing would be different. And, again, you

know, these are -- there are some questions. We're working with clients that we may end up doing some supplemental parametrics to look at some of these -- based on some of these results.

CHAIRMAN WALLIS: This looks sort of whimsical, the way it varies from plant to plant. And it's based on --

MR. BLEIGH: Well, this is not in the chronological order of the evolution of the test.

CHAIRMAN WALLIS: As it evolved you started bringing it closer to the strainer or something?

MR. WILLIAMS: Yes, sir.

CHAIRMAN WALLIS: Okay.

MR. WILLIAMS: Yes, sir.

CHAIRMAN WALLIS: Go back to Plant H, and put it on top of the strainer.

MR. WILLIAMS: We did an evaluation of that plant as one of the plants that we basically -- you saw the picture of the coatings. That plant essentially had no fiber loading and the coating load, and we did do that. We didn't do it as an official test. We did it as a sensitivity.

CHAIRMAN WALLIS: Then filled up with coatings? That's the one when everything filled up

with coatings?

MR. WILLIAMS: Yes, sir. So we didn't record that as part of the official test, but we did a lot of sensitivities, you know, that weren't necessarily official design basis tests to get some information and utilized those as part of the justification for why the results you see here are conservative under certain plant conditions.

MR. BLEIGH: Basically, the concern from the NRC staff after witnessing early tests was that we don't see the debris collected on the screen. We're seeing it in circulation and away from the screen. And to address that concern we -- the testing protocol changed to bring the debris at or as close to the screen as we could basically get it, so that, you know, the transport issues within the flume were taken out of the question.

So it was just a change in protocol to prove that even with the debris entered into the system at the screen, you know, we're now measuring head losses that in that view would be more representative and more conservative than if we were to leave it farther away from the screen.

CHAIRMAN WALLIS: But you're not going to go back and redo the other tests with it on top of the

screen?

MR. BLEIGH: Well, some sensitivity tests have shown it -- other than time it would not make much difference.

MR. WILLIAMS: We have one plant series themselves -- itself we did go back and retest for other reasons, because of the reload changes and we introduced the updated protocol in that test.

Okay. Ken?

MR. GREENWOOD: When we're doing our testing we -- the intent was to try and include the chemical precipitants in the test flume as one of the particular debris. And prior to the issuance of the WCAP we used the NUREG and ICET results to calculate quantities of materials and the types of materials.

At that time -- and we'll talk a little bit more about that later, but the surrogates were selected from manufactured surrogates. They were not produced as the WCAP suggests. And then later the WCAP, once issued, was used to validate the calculations, hand calculations if you will, that were produced previously and showed that our quantities were conservative.

MR. WILLIAMS: And conservative to the point of, in many cases, if we factored into the WCAP

we would have quantities in there in excess of 15 to 20 times that of what -- well, actually from a volumetric standpoint.

Now, we understand that we've got to look at the differences in the characteristics of the generated versus the manufactured, but in terms of volume in many cases we were 15 to 20 times that of what you would expect at the plant, just to be conservative.

MR. GREENWOOD: So as I mentioned, we were introducing these chemical byproducts into the strainer test itself using these manufactured materials. And the -- that's all the same information. So the chemical precipitant was -- oh, I'm sorry, I'm on the -- I'm ahead one.

And in an attempt to try and place the chemical precipitants at the tail end of the introduction, they were added last, just prior to starting the recirculation sump.

So this kind of illustrates how we came up with the chemical effects, and I think -- yes, I don't think we need to go through --

MR. WILLIAMS: When you say "walk us through the process here," we look at the WOG, the ICET, and other industry data, and at the time, in

November -- October/November last year, we were essentially utilizing mostly the ICET and other industry data. Then, as we said, once we get the WOG generator, then we're able to validate against that.

We then looked at plant-specific sump parameters, and we selected an appropriate manufactured material and basically it was sodium aluminum silicate, but we were utilizing it from a manufacturer standpoint, not from a generator standpoint. In essence, both are somewhat surrogates, but, you know, we were trying to use that to integrate it into the overall head loss testing, as you can see here.

So we do the flume testing with this introduction of the debris, in addition to the chemical constituents, measured the head loss that qualifies the strainer, in cases -- we'll also talk about that we collected downstream samples to get some information about how the bypass -- what kind of material bypassed and the characterization of that material.

CHAIRMAN WALLIS: Well, it looks as if you introduced these chemical precipitants before you started the pump?

MR. GREENWOOD: That's correct.

MR. WILLIAMS: Yes, sir.

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

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

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

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

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

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

MR. BLEIGH: Again, you have a high

percentage of these particulates in these debris beds recirculating. And so the concept that you have particulates being added to the debris bed after it swarmed actually took place on all these tests, because of the recirculation of these particulates once it passed the debris bed.

CHAIRMAN WALLIS: Well, the worst thing -- probably the worst thing is probably to have a fairly thin debris bed, and then keep making chemicals until you plug it up.

MR. BLEIGH: Again, it would probably depend on what the form of that chemical --

CHAIRMAN WALLIS: It looks like the thin bed of -- having a big, fluffy bed with the chemicals spread through it isn't so bad. It's just like the particulates.

MR. WILLIAMS: You have all kinds of -- that's right. It appears -- I mean, just like any other particulate in a large fiber debris bed, you have a lot of flow paths that as long as the --

CHAIRMAN WALLIS: All these people taking out fiberglass insulation may be going the wrong way.

MR. BLEIGH: But there's no guarantee on an actual accident condition to predict how much fibrous debris will actually be generated and how much

actually transports to the screen, which is why we continue to look at the entire range, you know, from a thin bed of fibers all the way to the maximum fiber condition postulated.

MR. GREENWOOD: Even for plants' predicted high fiber loads, we would go back and look at the low fiber conditions.

MR. WILLIAMS: Just information on the -- again, we were testing using tap water and doing -- the head loss results were adjusted based on dynamic viscosities.

Just a quick word about some of the surrogate materials we use. As I mentioned, the inorganic zinc, which was giving us problems from the EPA in the state we were testing, had a valuation to use tin powder. From an epoxy standpoint, if we weren't using chips in a low fiber condition, we would simulate the epoxy powder using a walnut shell flour arrangement.

Obsolete coating system -- as we had to utilize current coating systems and we had coating expert John Cavall and others evaluate, you know, the relationship between those. And just for latent debris we would use the SER recipe that was provided.

The chemical precipitants that were

utilized, the actual byproducts utilized or as shown -- and these are coming from results from the ICET test, and then subsequently confirmed by the WCAP. These materials were -- we basically used the best information we had available to come up with the quantities of these materials and the type of these materials.

Again, we did very plant-specific evaluations, and this even varied to some degree. In some cases, the plants themselves looked at the WCAP, came up with a quantity, and gave us the quantity that they wanted tested. In some cases, we did the evaluation.

MR. CAIN: I'll take this one.

MR. WILLIAMS: Mr. Cain is going to talk about penetration tests.

MR. CAIN: I'll just give you a quick overview of our downstream sampling apparatus. Built into the flume system downstream you'll see in our next -- our next slide we have three isokinetic sampling ports located in the six-inch diameter -- oh, there it is -- conduit directly downstream of the strainer. So the end of the flume is right here. The strainer is immediately upstream of that. Our sampling ports are downstream of that.

We have three independent ports, each discharging from the pipe. We actually had a vertical air over water manometer board that we used to set the proper velocity head in the ports to ensure that the velocity at the entrance to the ports was equal to the --

CHAIRMAN WALLIS: That's how you sample whatever gets through the screen, is that it?

MR. CAIN: That is correct, yes. And we do it isokinetically, so that we know how much of a volume we've taken off of the -- we've taken off of the flow loop.

Here is the strainer. Okay. Downstream of the strainer we have our pressure taps for head loss. Downstream of that we have our isokinetic sampling port. Now, the downstream piping is sized such that the velocities in the downstream piping are high enough to keep the material suspended and moving, and to minimize preferential sorting of the material based on size and density.

So we pull this off. We have our sampling ports over here. We adjust the height of this. It's a gravity-driven system. We adjust the height of this to ensure that the velocities at the inlet ports are equal to the velocities in the tube. And we collect

our sample over a given amount of time.

We take 10 -- we take samples every 10 minutes during the first hour of testing and every 20 minutes thereafter until reaching our termination criteria. And then, those samples are analyzed by an external laboratory.

MR. WILLIAMS: As Stu said, we take the samples and we basically want to see a time history of the material that is getting through. And as we discussed with the staff yesterday, one of the things that we -- there's a difference between taking the samples and how you utilize the data. We were looking for a couple of trends.

Do we get the K function even with a low fiber condition? I mean, there was questions raised as to, well, does an integrated test -- when you're doing a head loss and a bypass test at the same time, is one contradictory to the other? You can basically argue it both ways.

I think if you get a higher differential pressure, you will be forcing more material through, whereas if you did a separate test and you had lower amounts of material then you're getting another set of results. I mean, what we did was take enough samples on the high fiber conditions and to samples in lower

fiber conditions, and we're essentially looking for trends.

I think from a particulate standpoint, when you utilize the WCAP -- I mean, the assumptions that are made that 100 percent of particulates gets through, that's going to be consistent.

We were looking at hopefully being able to utilize the data on the fibers themselves, where we would get information from the SEM evaluation such as this, where we actually -- based on sample size we had the fiber lengths and the diameters of the fibers that penetrated, characterized, and so that we can use that data for looking into how much blockage you could potentially get in the -- you know, going towards the fuel assemblies themselves.

We were getting very consistent results with some of the stuff that Enercon/Alion was pointing out to typically the largest fiber we would -- length we would get, though, is about 2,000 microns, all the way down to 100 microns. So, in essence, it has almost started to look more like particulates than the fibrous material themselves.

But we did get a distribution of sizes, and so that does give us some information. We also saw a fairly loose correlation between the hole size

and the size of the material -- or fibers that would get through -- the length of material -- excuse me, the length of the fibers that would get through.

You would get more of the medium length fibers with the smaller hole size than you would the larger, so there was a somewhat loose correlation but it was evident.

Last thing is termination -- one of the last things, termination criteria. Very similar to the BWRs -- and, again, we would use the increase in the five-minute average is less than one percent and head loss, and we had a calculated time based on the flow rates of full -- five full volume turnovers of the flume.

One of the things we also provide the plants is information in order to do a data extrapolation. What percent of change will you see in that test termination, so that you can take a look at that and see at what point -- in other words, if you extrapolate that out, and what would you cut the pumps back, and your NPSH margins become very large. And so that gives you assurance that even with head loss creep that you wouldn't exceed your NPSH allowable.

This just gives you an overview of the data acquisition system that we utilized. We were --

this is flow rates. This is through the overhead piping to the upstream piping. This is a head loss curve that's being generated here. And what you see in the blips here is when we were taking the bypass samples, the isokinetic bypass sampling, showing overall head loss here.

And then, we have a rate of change and a five-minute average. This gives you flow rates down here also, and this particular one was about 50 gpm in this part of the test.

Jim Bleigh of PCI is going to walk us through -- we thought it would be informative to see some of the design drawings and some photos of the existing replacement strainers. As we said, our strainers are ranging from 800 square feet to over 7,000 square feet. I don't know if we -- if you added up all of the strainer square footage existing, I don't know if you'd reach 7,000 right now. But --

CHAIRMAN WALLIS: You're doing so well, I don't think we need to take a break, do we? Just continue to --

MR. WILLIAMS: No, I think we -- if we're okay to do that. We're probably -- depending on the questions, we're probably 10 minutes, 15 minutes from finishing.

CHAIRMAN WALLIS: Okay. So you can go away and bring your data after lunch.

(Laughter.)

MR. WILLIAMS: Okay. All right. Jim?

MR. BLEIGH: Okay. This is an arrangement of vertical Shurflo strainers on a suction plenum that basically partially covers the current sump opening. Obviously, the part of the sump opening that is not covered with strainers is covered with cover plate to create the suction plenum below.

CHAIRMAN WALLIS: You are filling up the sump with strainers.

MR. BLEIGH: No, this is actually on floor level. And actually, the plenum is above the floor level.

CHAIRMAN WALLIS: Oh, okay, okay.

MR. BLEIGH: And so actually this is -- this particular client has a really high water level, and so we're in submergence with lots of submergence, and the sump pit is below. And this simply provides the platform on which all of the modules can be placed.

CHAIRMAN WALLIS: Okay.

MR. WILLIAMS: Yes. This was the kind of plant everybody wanted to have. They had 12 feet of

NPSH margin, no fiber. There was a --

MR. BLEIGH: And the next two slides is actually a picture in our factory of this arrangement, so this is what it looks like assembled in our plant prior to shipment.

MR. CARUSO: How do you decide whether to stack the disks vertically or horizontally?

MR. WILLIAMS: It's just a matter of the plant arrangement and the space provided by the client in terms of how I put the most space of screens in the space, an arrangement that they have provided.

MR. CARUSO: I was just thinking in a case like this you could stack them either way. How did you decide to do it this way?

MR. WILLIAMS: Well, this takes up less floor space than going horizontal, more square footage.

MR. BLEIGH: So the footprint is much smaller this way than the other.

CHAIRMAN WALLIS: But the discharge pipe just goes straight down?

MR. BLEIGH: Well, actually, it's just the opening in the sump pit collects water out of the suction plenum, and then the suction pipes are actually down int he --

CHAIRMAN WALLIS: Well, it's full of water. But there's a hole in the middle of these things that --

MR. BLEIGH: Correct. That's right.

CHAIRMAN WALLIS: And you see the pipe coming out of the bottom, which goes straight down to the sump pit.

MR. WILLIAMS: Right in this plenum, and then it comes into the sump pit.

MR. BLEIGH: This core tube here goes all the way down and interfaces with this base plate. This is all open here sitting on the floor. So once the water gets into the plenum area it will go towards the sump and then spill over the sump into the sump pit, and then it will be sucked by the suction line there.

CHAIRMAN WALLIS: There is a plenum area there. There is an enclosed plenum.

MR. BLEIGH: Yes, all of this is a closed plenum.

MR. WILLIAMS: That's correct.

MR. BLEIGH: Everything that that sits on is a sealed plenum.

MR. WILLIAMS: But to answer your question, in many cases the water level at the onset

of recirc demands whether or not, you know, it gives you -- do you have this opportunity to stack like this, or must you spread it out? And if you've only got two feet of water level, in this case we probably had five or six feet --

MR. BLEIGH: This is like 4,600 square feet of screens.

MR. WILLIAMS: This gives you a picture of --

MR. BLEIGH: From above what it looks like.

MR. WILLIAMS: The big picture.

MR. BLEIGH: Okay. In the next arrangement we have, again, a single sump arrangement in a plant. There is no screen redundancy in the sump, and so basically we have two trains connecting to a sump cover. Each of these trains are the same size, and they can draw water from either side into the common sump and then to the -- through the ECCS. This is a horizontal strainer.

MR. WILLIAMS: All right. This is the other arrangement that you mentioned.

MR. BLEIGH: Right. And then, this is a picture of this unit installed. This is the only unit that has been installed of our product so far. So you

basically have the pit over here, and the suction pipes coming out and connecting to the end of the strainers here, and then following along the outer wall.

This is another horizontal arrangement in a different plant. We have actually floor mounts. The suction lines came to floor level and ended there. This plant currently had existing like 25 square feet per train as its existing screens. And when they install ours they will have approximately 1,800 square feet on each train. So it's a significant improvement in the surface area.

This train is moving this way along the outer wall. There wasn't room here with block -- you know, maintenance activities during outages, and so we're piping it over to this area where the same number of modules will exist.

MR. WILLIAMS: There's just no two of these footprints that seem to be alike, unfortunately.

MR. BLEIGH: This is actually another horizontal strainer that connects to a cover plate on a sump pit. It's a single train. There's not two for this particular client. I think there's 14 modules that go in one direction. Again, this pipe will work itself around and connect --

CHAIRMAN WALLIS: Now, that central pipe, is that the same diameter all the way through?

MR. BLEIGH: In this case, yes.

CHAIRMAN WALLIS: It just has different hole sizes.

MR. BLEIGH: Right. So the hole sizes near the suction end are going to be very small, and then as we move this way the holes get larger. So that, you know, at least in clean water, you know, we're drawing the same water on this end as this end. That way when the debris is collecting to the screen it's collecting at the lowest flow rate possible.

CHAIRMAN WALLIS: This is a just a Bernoulli effect, is that what --

MR. WILLIAMS: Yes.

CHAIRMAN WALLIS: Okay.

MR. WILLIAMS: Absolutely.

MR. BLEIGH: This is not a terribly good picture, but we've tried to give some idea -- this is an existing screen in a plant, and this is the actual plant I think that --

CHAIRMAN WALLIS: The existing screen. That's about the size of a person, is it?

MR. BLEIGH: Yes. This is the existing screen. And then, if you go to the next picture, this

is what's replacing those is this.

CHAIRMAN WALLIS: It's two orders of magnitude bigger or something like that.

MR. WILLIAMS: It's probably closer to ten.

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

MR. WILLIAMS: Not ten orders of magnitude, ten times.

CHAIRMAN WALLIS: Two orders of magnitude.

MR. WILLIAMS: Yes, ten times the size.

CHAIRMAN WALLIS: Sixty times as big or something like that.

MR. WILLIAMS: Right. And we've gone from, you know, less than 50 square feet to several thousand.

CHAIRMAN WALLIS: It says on the last page.

MR. BLEIGH: And this is what that particular screen looks like assembled in our factory before shipment.

MR. WILLIAMS: So, in summary, as I noted before that this testing that we've done has evolved over time based on some good input and interface with the staff as well as the clients and our own evaluation of the results based on the PWR -- BWR

precedent.

The strainers are ranging from 25 to 75 times the existing stainer area, so you can see there's a significant amount of area that is being added in. Downstream effects evaluation are ongoing, and we're continuing dialogue with the staff on how those -- that information is going to --

CHAIRMAN WALLIS: That's a pretty dramatic change, isn't it?

MR. WILLIAMS: Absolutely.

MR. BLEIGH: Very, very dramatic.

MR. WILLIAMS: Absolutely. I was over in engineering at Browns Ferry in the '90s when we replaced the strainers. I had a total of 40 square feet for four strainers. I had a common suction header and had 40 square feet, and we ended up with like, you know, 800 per intake per suction header.

CHAIRMAN WALLIS: EDF is doing about the same thing, isn't it? They're developing the same --

MR. WILLIAMS: Yes.

MR. BLEIGH: I would think so, yes.

MR. WILLIAMS: They actually -- I don't know the exact numbers, but I actually think they're even -- they may be even a little bit larger.

And that's all we have.

CHAIRMAN WALLIS: Why did we allow so much time for all of these presentations? Must have been Ralph.

So we're now three hours ahead or something? No, not quite. I guess -- and we're going to have lunch, so we're going to be two hours ahead. GE is all we've got left today?

PARTICIPANT: Right. That's all we've got left.

MEMBER KRESS: Let's take a long lunch.

PARTICIPANT: Do you think anyone wants -- no, let's see, can we go --

CHAIRMAN WALLIS: We're not allowed to go ahead, are we?

PARTICIPANT: No, we're not allowed to go ahead.

CHAIRMAN WALLIS: Well, we could have sort of a roundtable discussion. Now, tell us what really happened or something.

PARTICIPANT: We could do that, yes.

CHAIRMAN WALLIS: I don't think that that's --

PARTICIPANT: We could just discuss.

CHAIRMAN WALLIS: Yes. Everyone is going to be here anyway.

MEMBER BONACA: I had a question on the chemical effects. I mean, do you have any preliminary results? We heard from the previous vendor that they had trouble, they have plugging, and they are attempting to address it through different approaches. I mean, what about your experience with chemical compounds?

MR. WILLIAMS: Well, as I said, we -- we used the manufactured chemicals as an integrated part of the test. One of the things we did note is that in one or two of the tests where the chemical constituent was a large part of the overall particulate we did get some substantial increases in head loss.

We're meeting with our client base, and basically outlining some of the open issues and discussing some resolution paths right now. I think one of the things we probably need to do as an industry a little bit better now is get our heads together and get everybody going in the same direction on this particular issue.

It's not necessarily conducive to have five different, you know, screen vendors trying to solve this problem independently of each other. That's -- I think that's probably or hopefully what we'll be looking at going forward as we're working

together.

CHAIRMAN WALLIS: It's all a work in progress. And the real -- the real proof is that what you come up with at the end is justifiable.

MR. WILLIAMS: Yes, that's correct.

CHAIRMAN WALLIS: And in a way, it's not appropriate for us to look at the difficulties you may have now that you're going to resolve. So it's appropriate just to look at the finished product, unless there's some really big surprises. Did you have any big surprises?

MR. WILLIAMS: Any big surprises?

CHAIRMAN WALLIS: Well, middle sized.

(Laughter.)

Interesting surprises.

MR. WILLIAMS: We had a couple of configurations set up with specific debris mixes, flow -- a combination of flow rates, debris mixes. It seemed like critical amount of fibers that we -- we got some head losses that we -- were a little bit unsuspecting.

Now, what we did, Dr. Wallis, every time we went into a test we would do a prediction on 6224, and then say, okay, that's kind of the upper bound target, and let's see where we land there. We had one

or two mixes that --

CHAIRMAN WALLIS: See, this is the thing which has characterized previous work. We had this 6224 correlation, and then Los Alamos did some tests and found out that under some conditions you tugged along and suddenly there was a big increase. And then, people in the northwest did some tests and they found that putting things in different orders and some conditions gave you very different results.

And then, ANL did some things, and I think in almost every case there was something which might not have been anticipated which happened. And so that's really the concern here is that -- have you done enough -- have you covered enough of the territory to find out the places where unusual things tend to occur?

MR. WILLIAMS: We feel like we've done a huge suite of varying debris mixes, flow rates, debris placement. I mean, as you saw from our chart, you know, we've had a -- we've got a large variation in which we can look at the data and say, "What does that tell us?" And it does tell us a couple of things.

CHAIRMAN WALLIS: And if there's one anomaly in a hundred tests, then maybe the probability 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

wondering.

MEMBER KRESS: I think they can.

CHAIRMAN WALLIS: Okay. So is it okay if we come back at 1:30, or are you saying that you want to come back earlier?

CHAIRMAN WALLIS: If it's a closed session, will we be coming back at all?

CHAIRMAN WALLIS: Well, that's -- do you want to ask any more questions this afternoon of these folks, or can they go now?

MEMBER MAYNARD: Well, I think they can go now. Again, all this is work in progress. I've really been interested in their approach, in their capabilities, and what they're doing. I don't have any additional questions on that, so I -- from my perspective, they can go.

CHAIRMAN WALLIS: Okay. So --

MEMBER KRESS: I think so. You know, what they're doing I think looks appropriate, and they're covering the range. And I would just like to see what the results are. And I don't -- you know, I can't ask them any more until then.

CHAIRMAN WALLIS: Yes. Okay. So you folks can leave, and thank you very much for being here. And that also applies to --

PARTICIPANT: Anyone who is not going to be here for the GE section.

CHAIRMAN WALLIS: That applies to NEI, too? Are you going to be here for the GE section? You'll be here for that.

Okay. So we're going to take a break until 1:30, and we will hear about the GE work then.

(Whereupon, at 12:12 p.m., the proceedings in the foregoing matter went off the record for a lunch recess.)

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

John Butler
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Nuclear Energy Institute
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NEI

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

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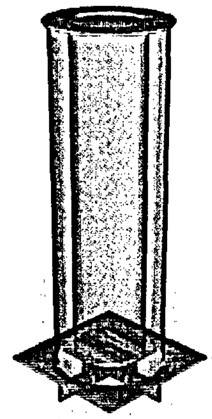
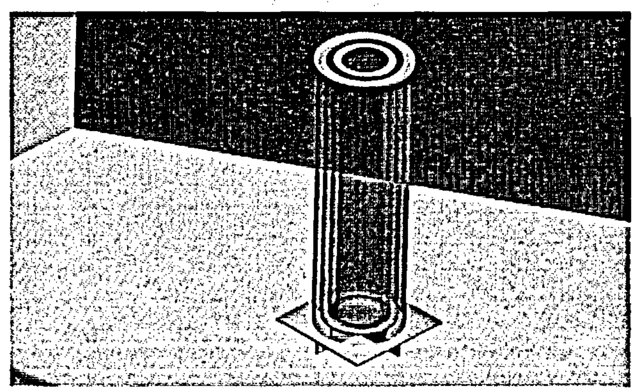
TPI

Outline of Information

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





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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

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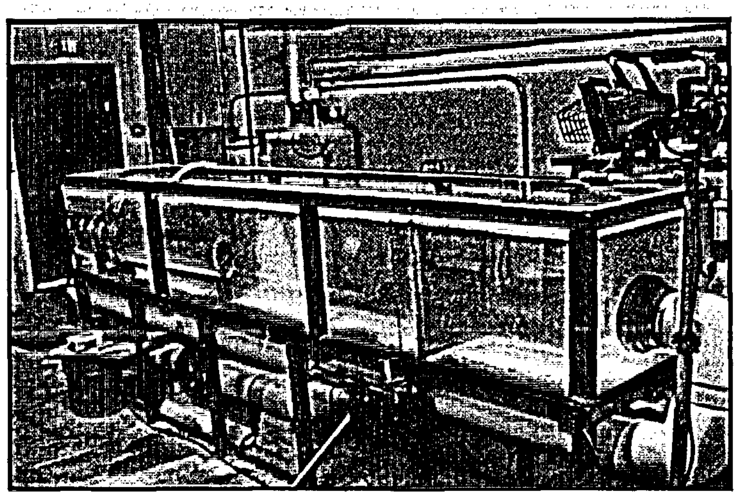
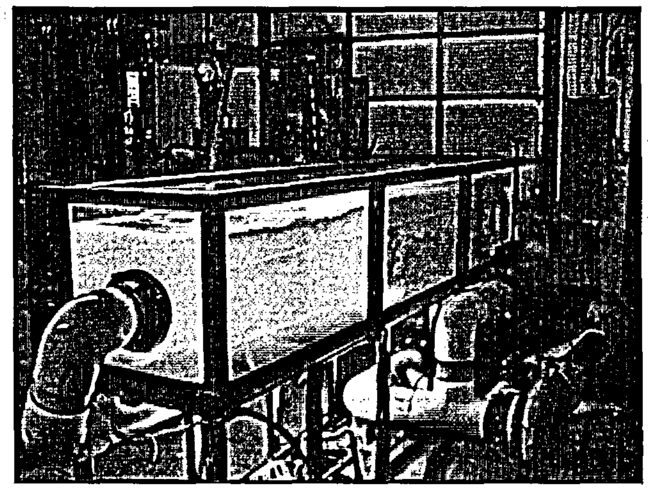
TPI

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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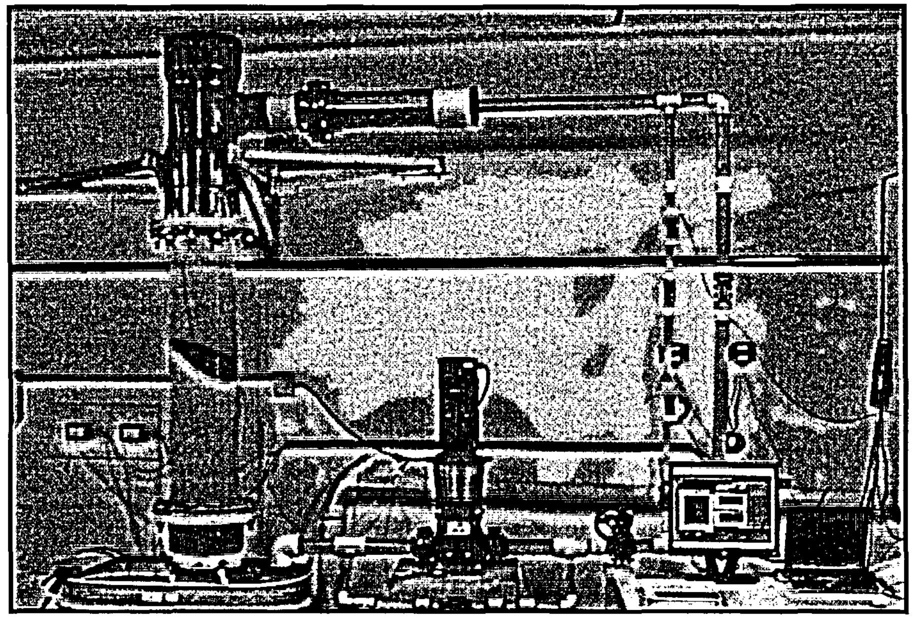
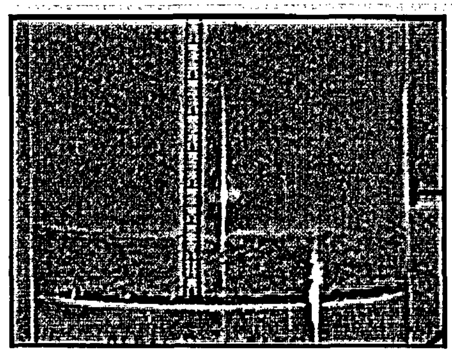
Material Head Loss Testing

- 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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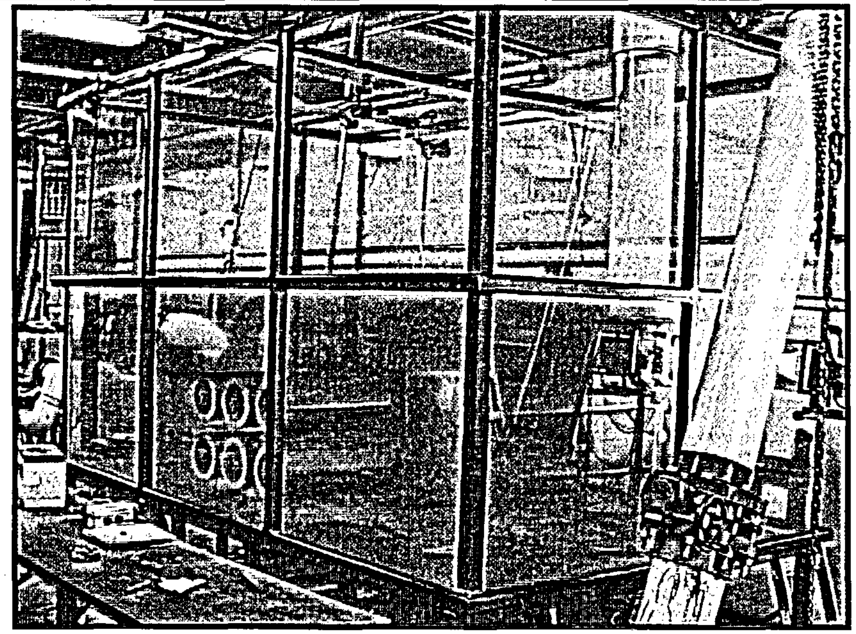
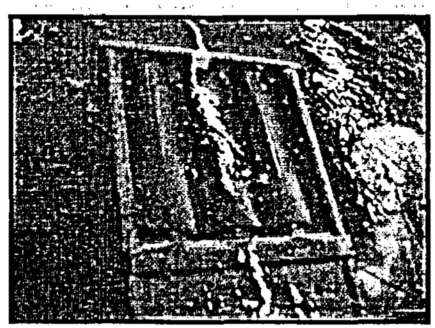
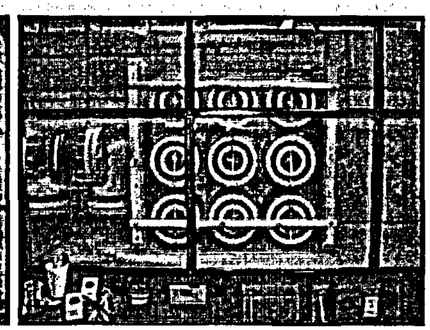
Prototype Tank Testing

- 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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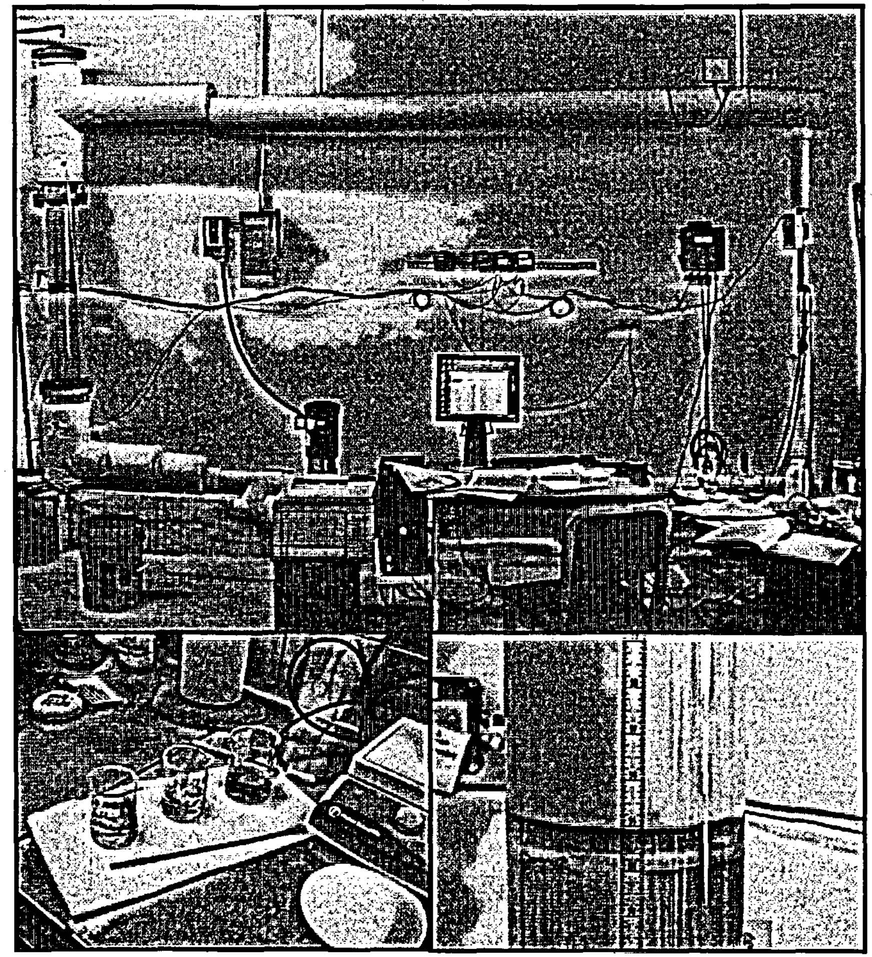
Chemical Effects Head Loss Testing

- 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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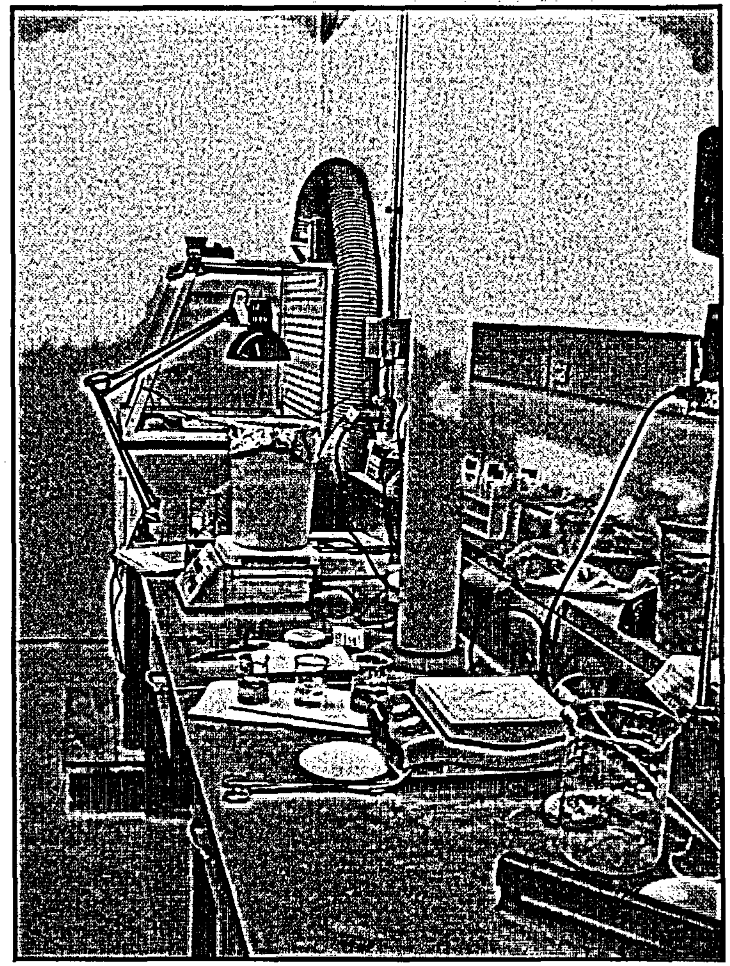
Bench Testing

- 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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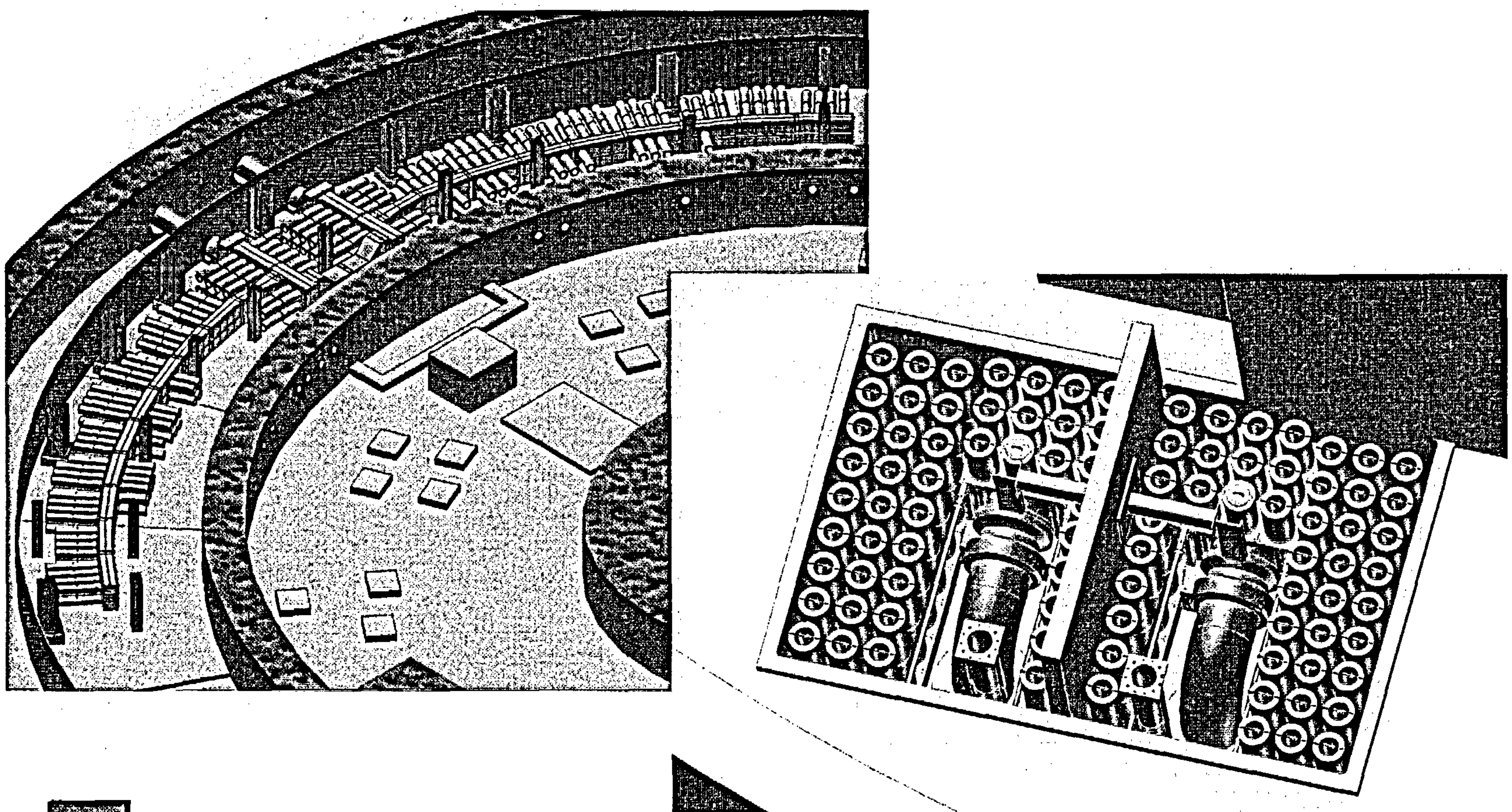
Replacement Strainer Designs



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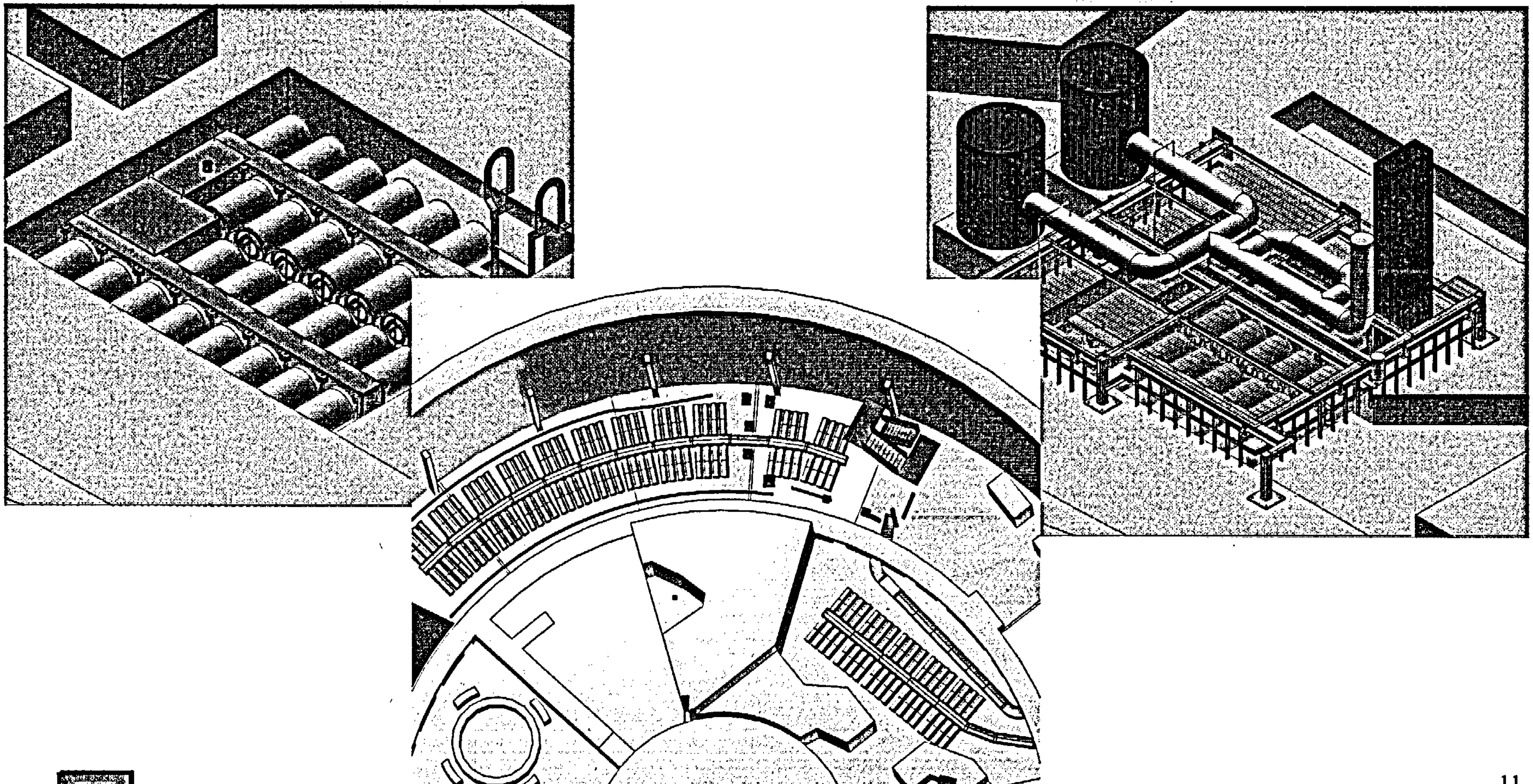
Replacement Strainer Designs



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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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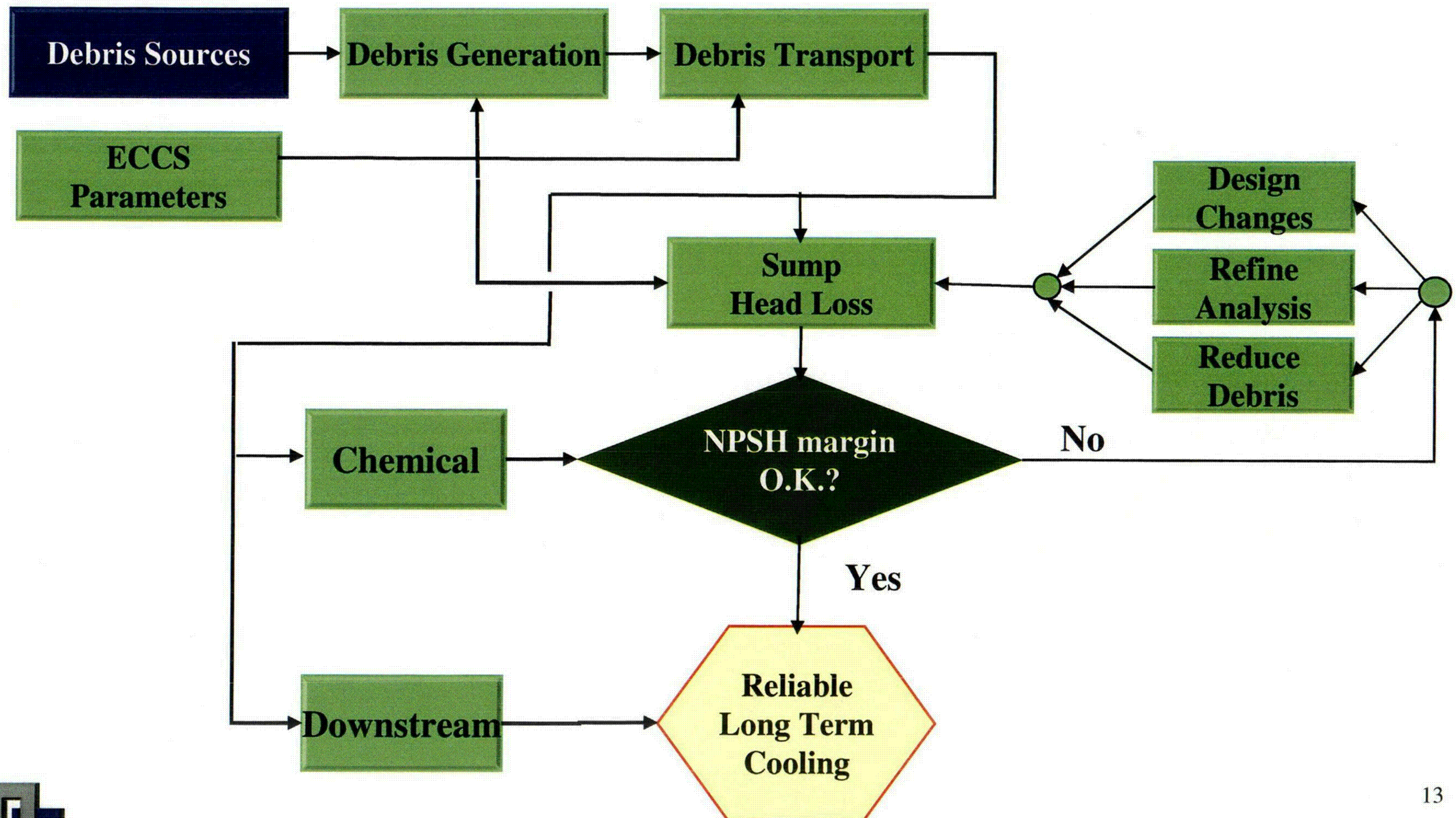
Major Steps in Assuring Reliable Long Term Cooling



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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

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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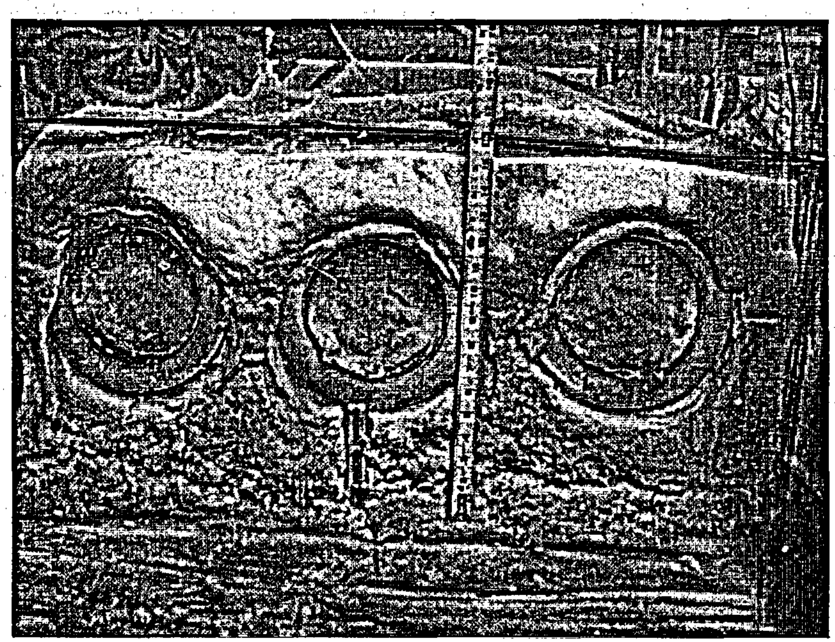
Array Testing (cont.)

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.

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 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

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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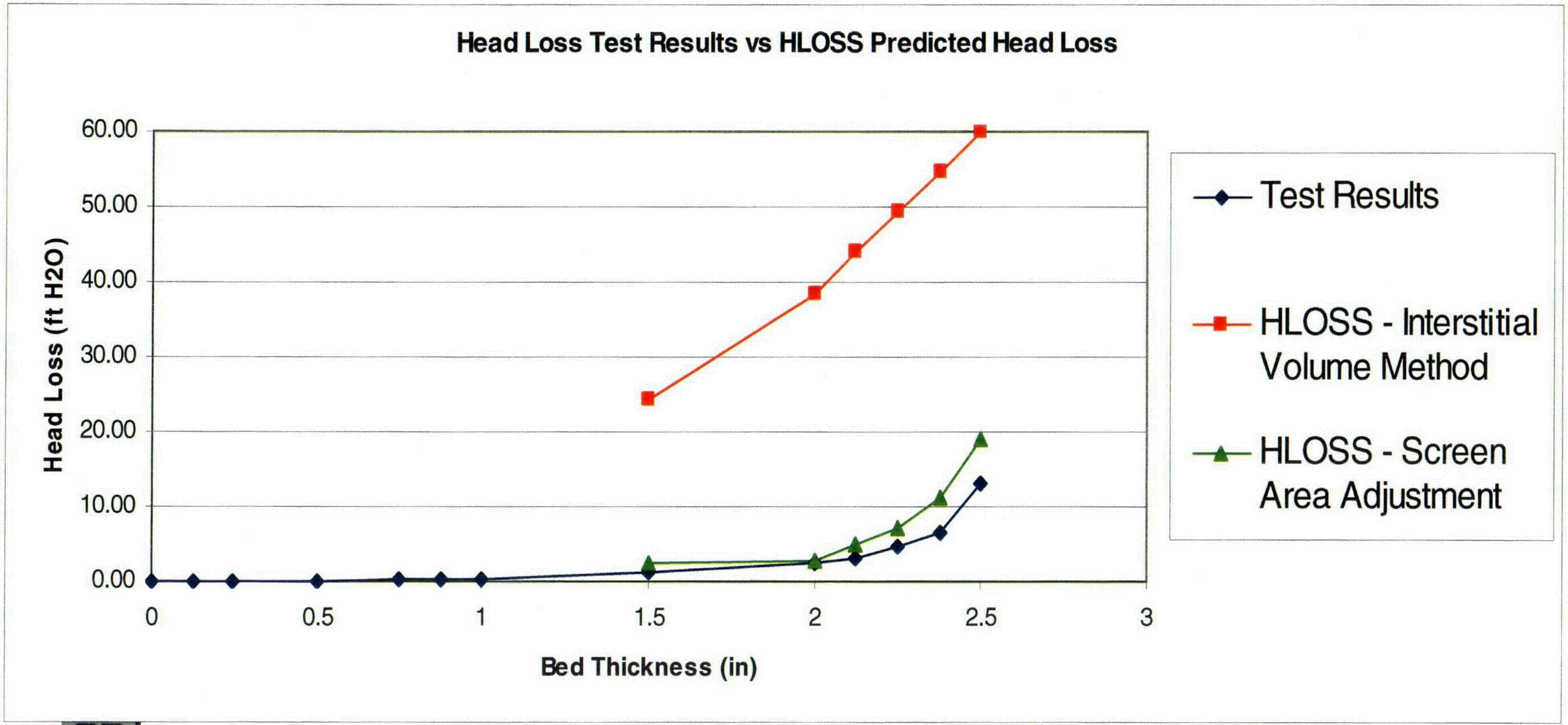
Array Testing (cont.)

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.

Array Testing (cont.)



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Array Testing (cont.)

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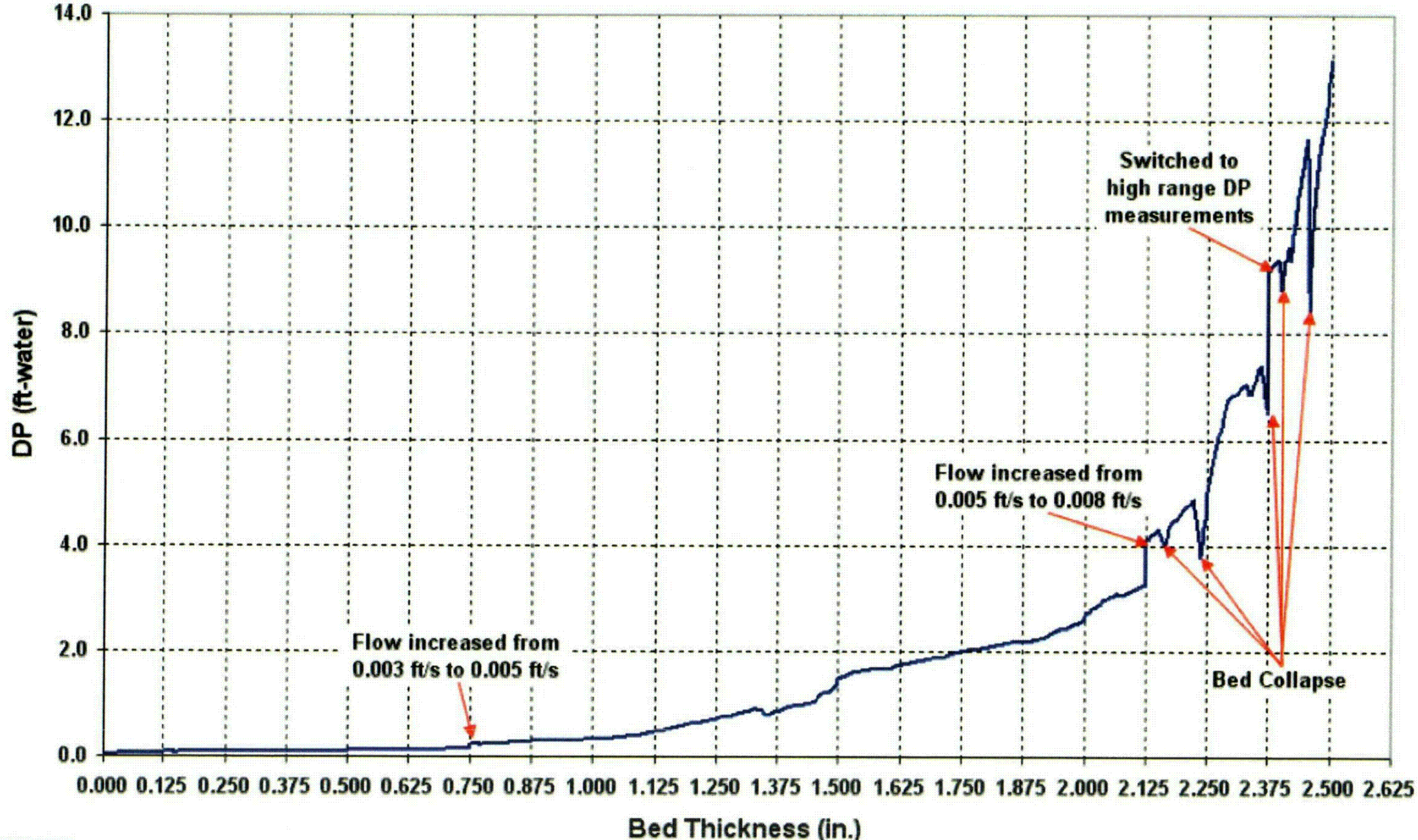
Array Testing (cont.)



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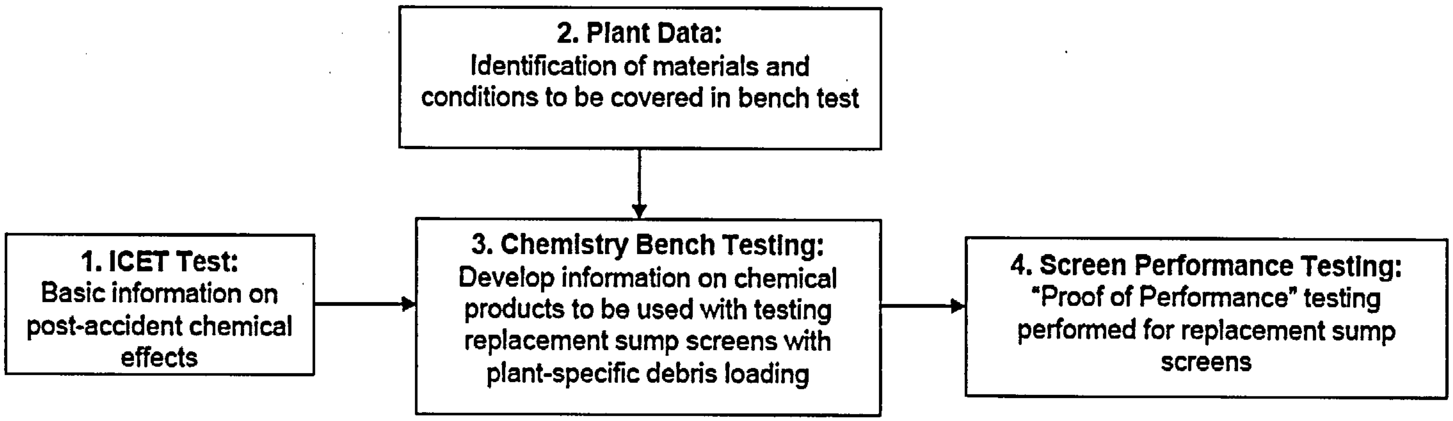
Head Loss due to Chemical Effects

- 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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TPI

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

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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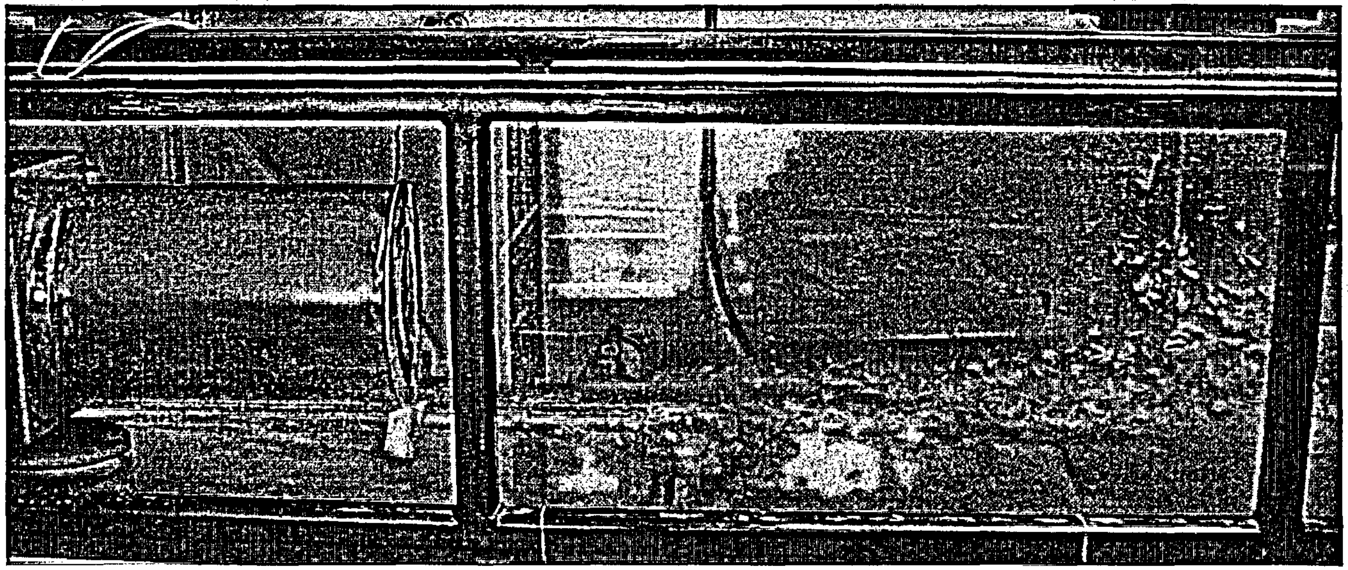
Fiber Debris Bypass Testing (cont.)

- 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.

Fiber Debris Bypass Testing (cont.)



Fibrous Debris Traveling to the Top-Hat Strainer

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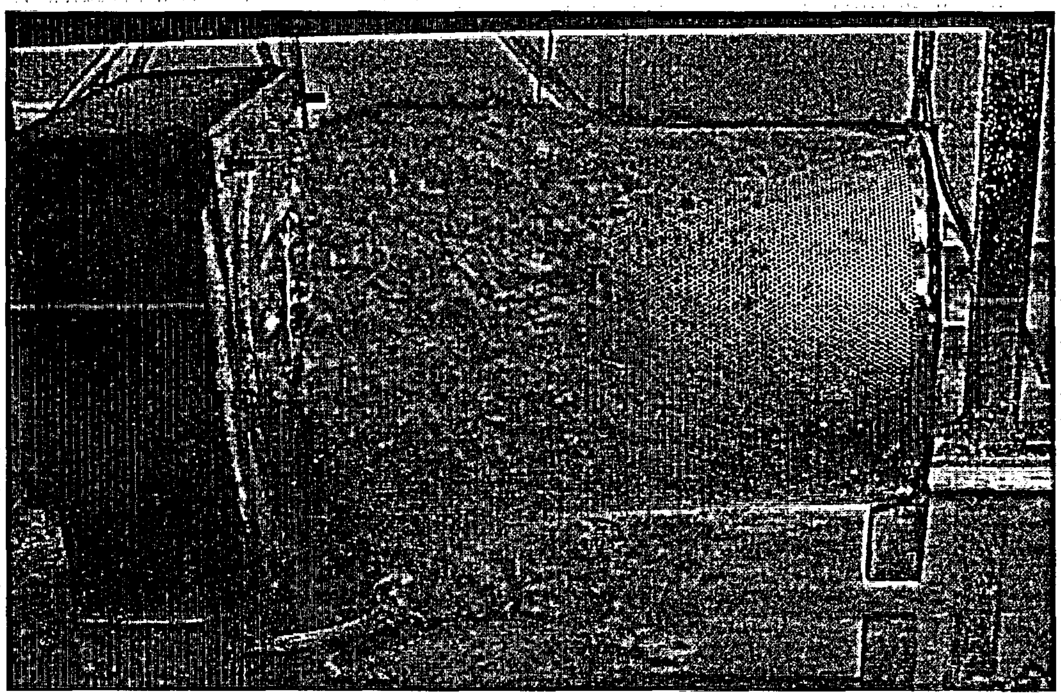
Fiber Debris Bypass Testing (cont.)



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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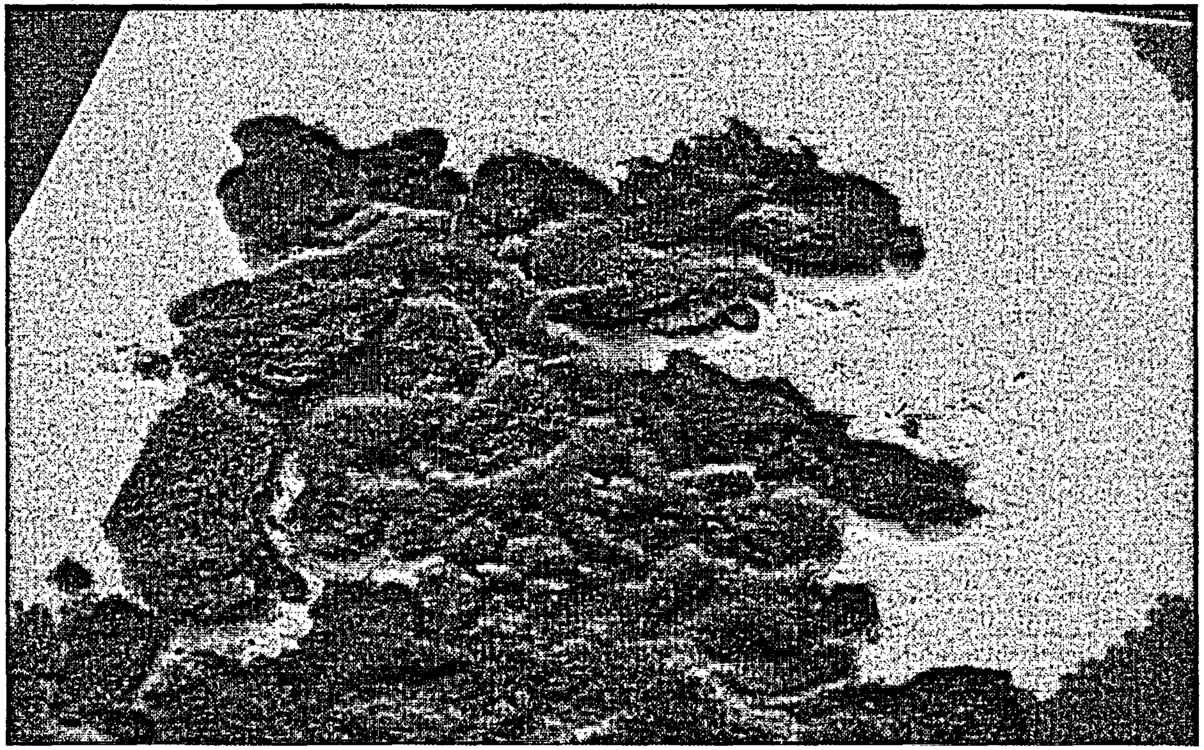
Fiber Debris Bypass Testing (cont.)

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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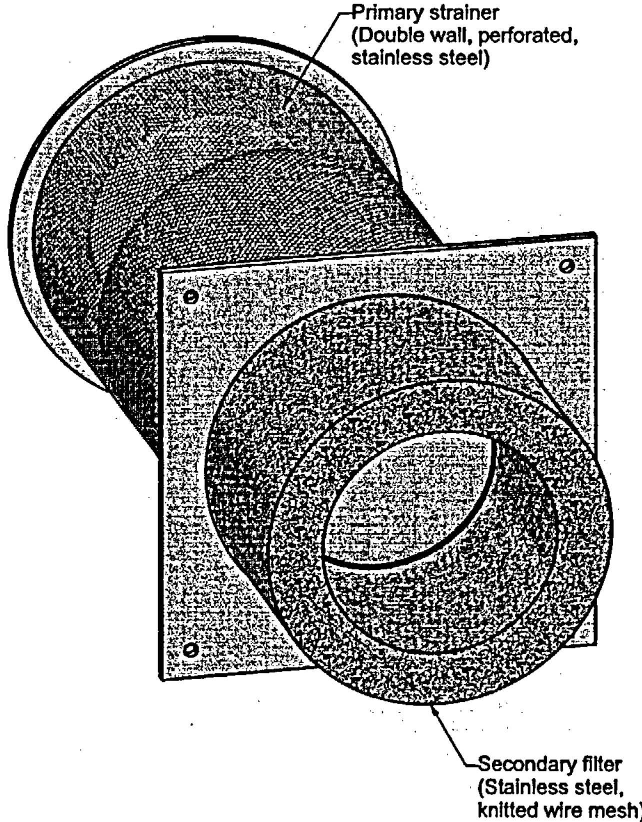
Fiber Debris Bypass Testing (cont.)

Enercon's

Debris Bypass Eliminator



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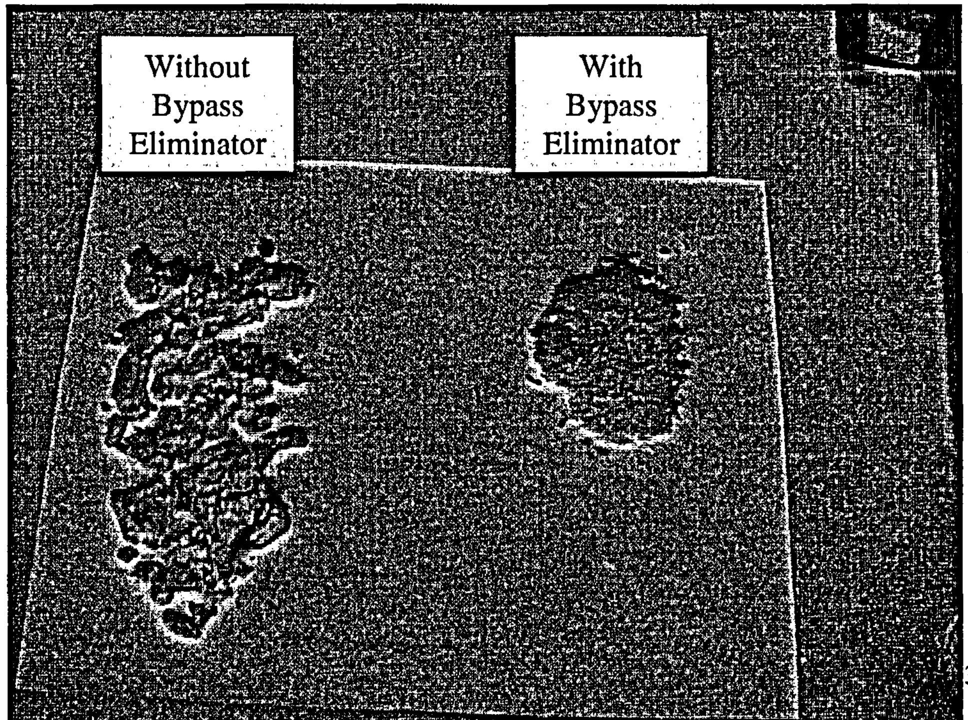
Fiber Debris Bypass Testing (cont.)

- **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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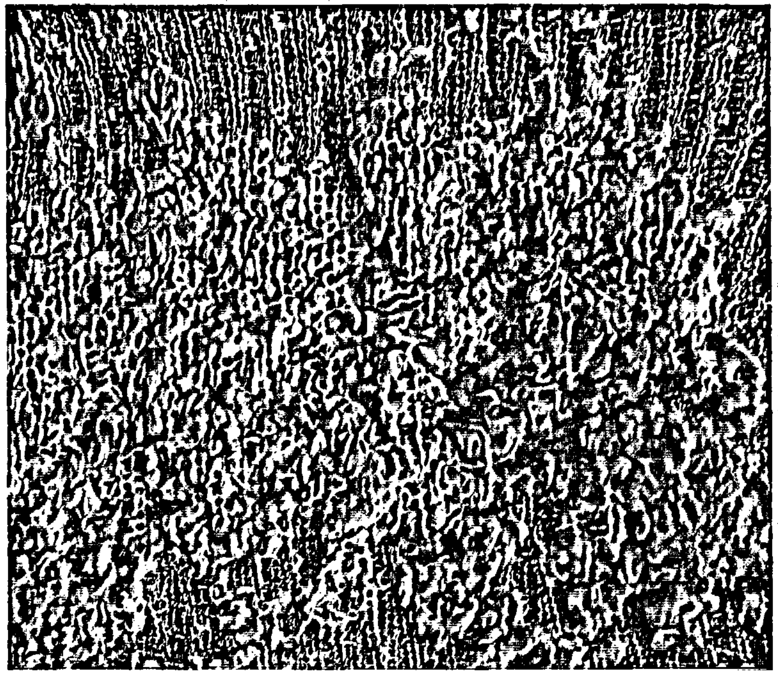
Fiber Debris Bypass Testing (cont.)

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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PCI
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Solving Flow Problems Since 1894

ACRS T-H Phenomena Subcommittee GSI-191 Issues Meeting

Rockville, MD
August 23-24, 2006

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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

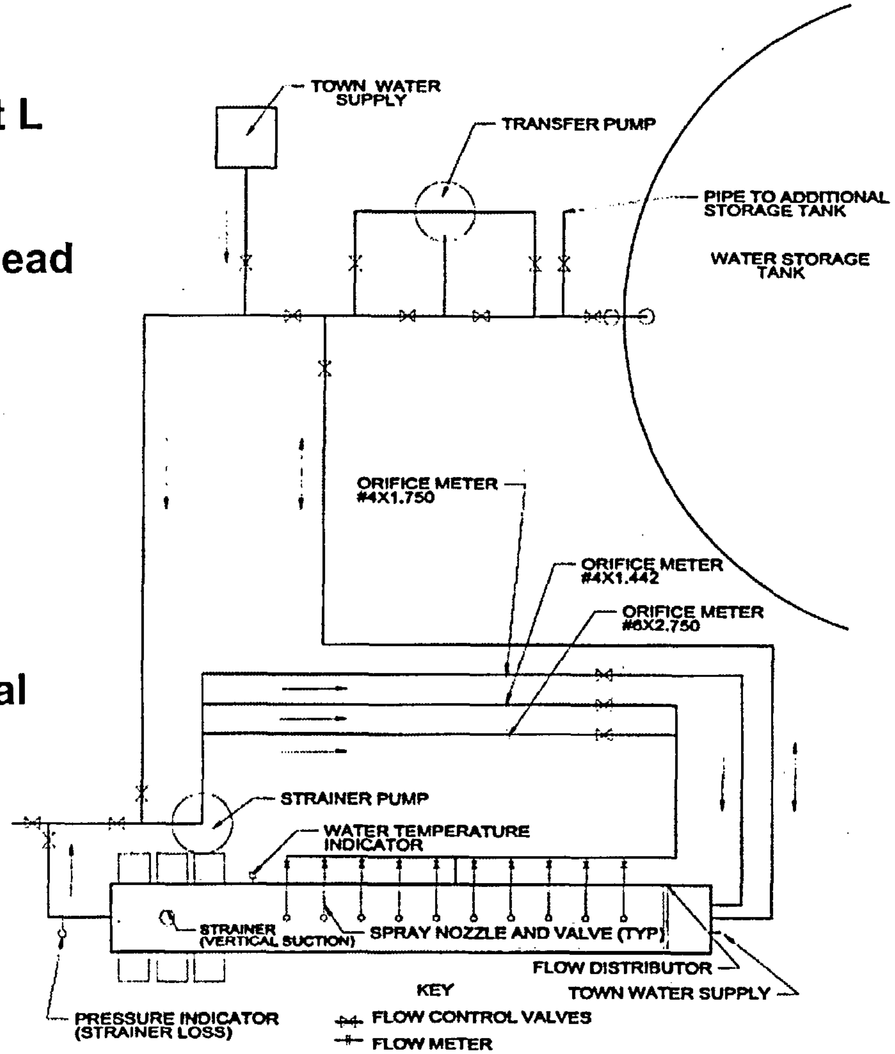
- Facilities Overview
- Overview of Licensees & Strainer Design Parameters

> Specific Topics

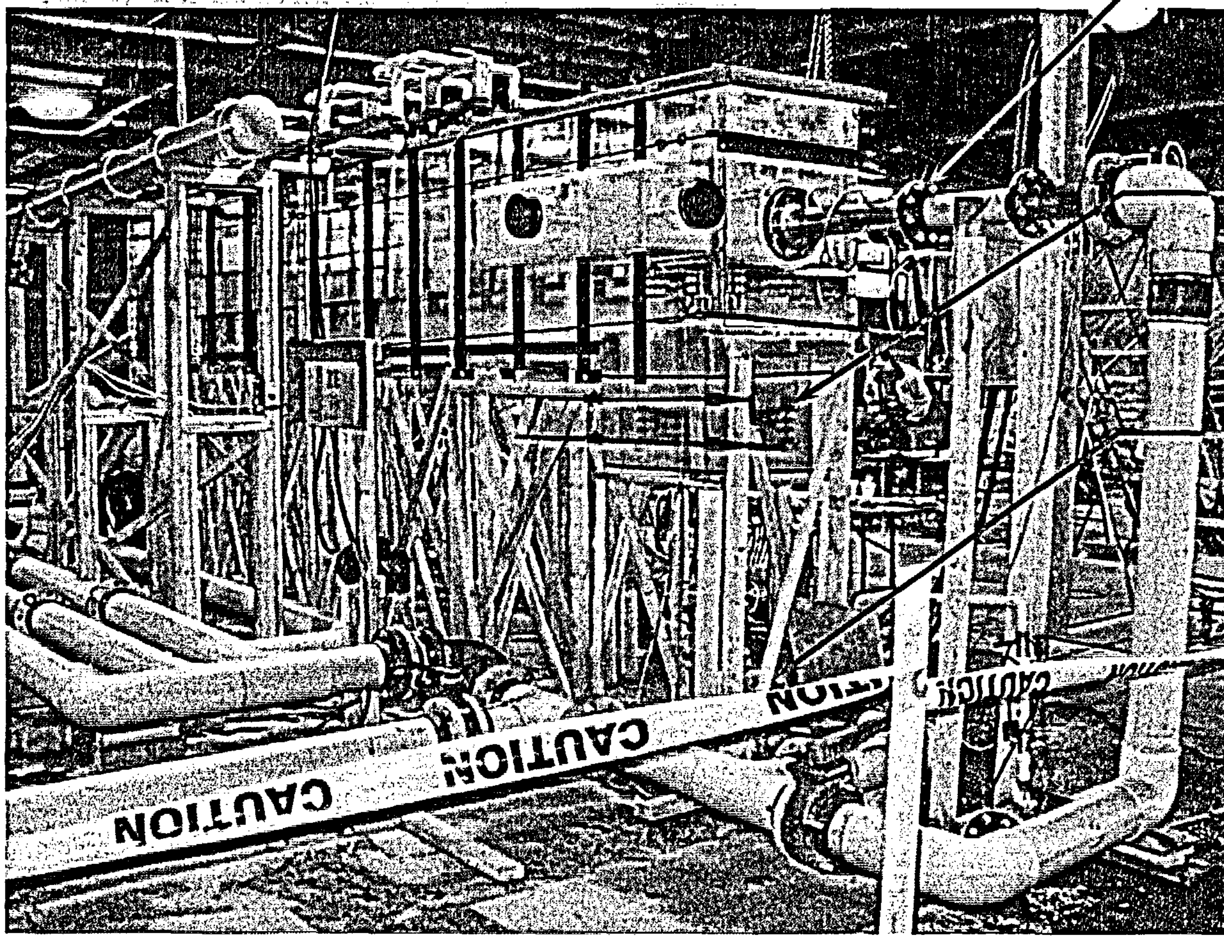
- Scaling Methodology
- Debris Preparation Methodology
- Debris Introduction Methodology
- Head Loss Due to Chemical Effects
- Screen Penetration Testing
- Termination Criteria

> 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



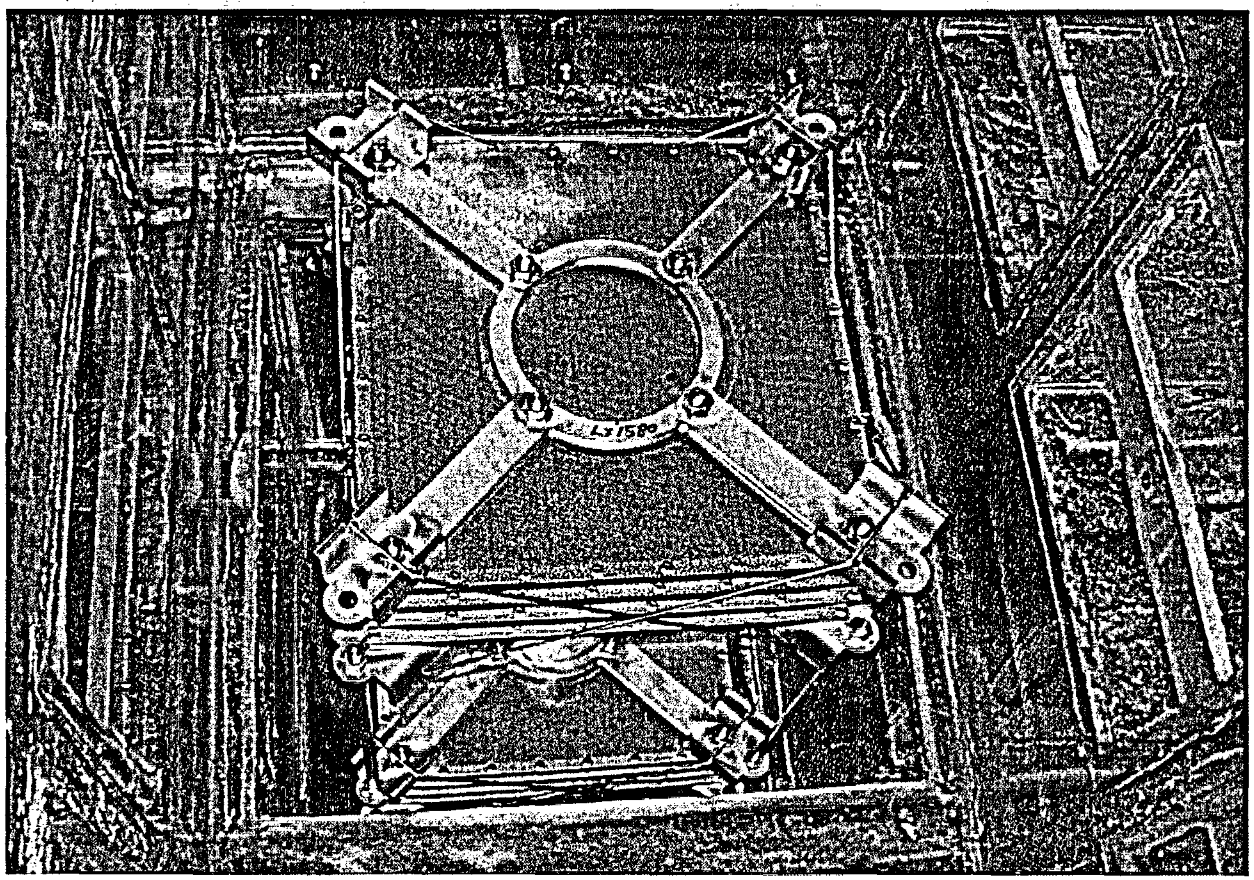
Horizontally mounted suction piping

Depressed pit

Vertically mounted suction piping

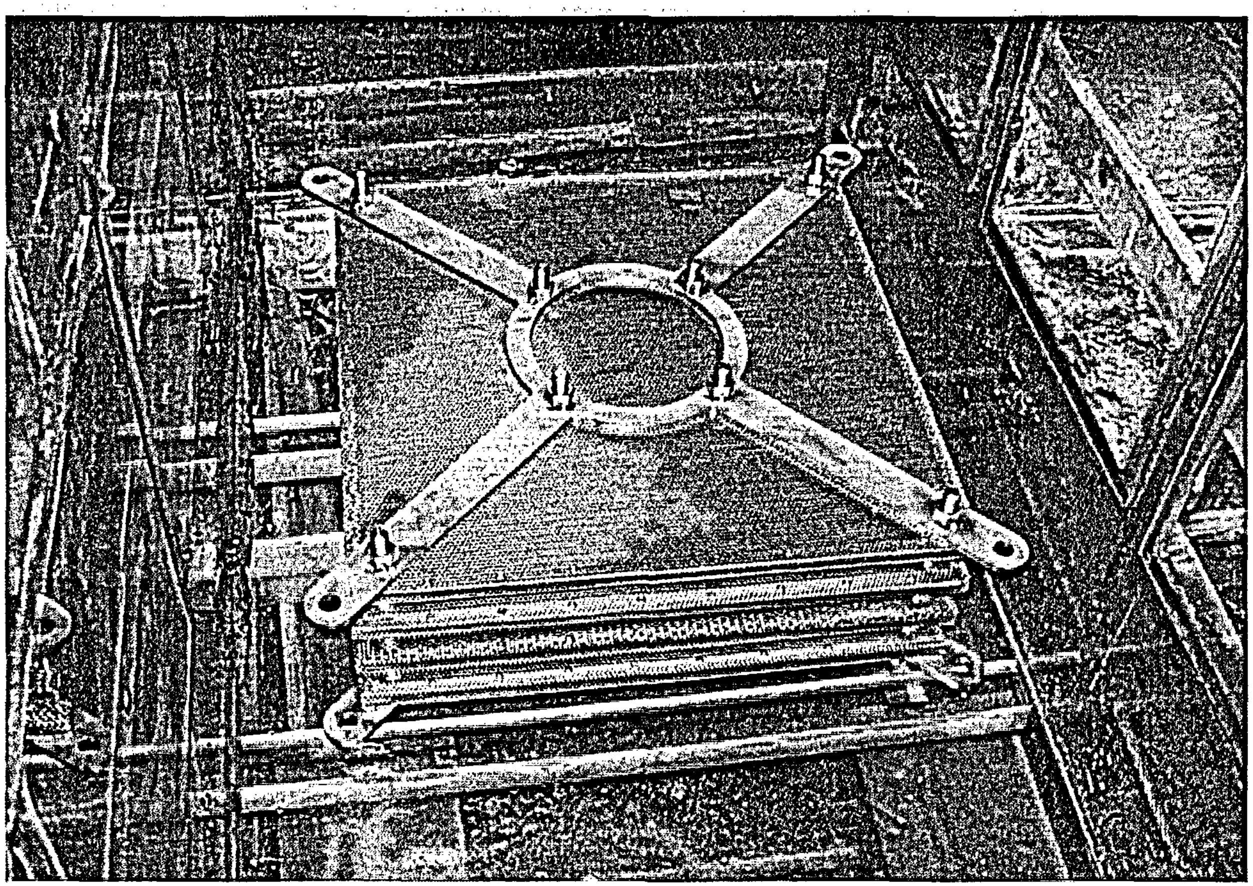
> Facilities Overview

- *Prototype Strainer Installed in Depressed Pit*



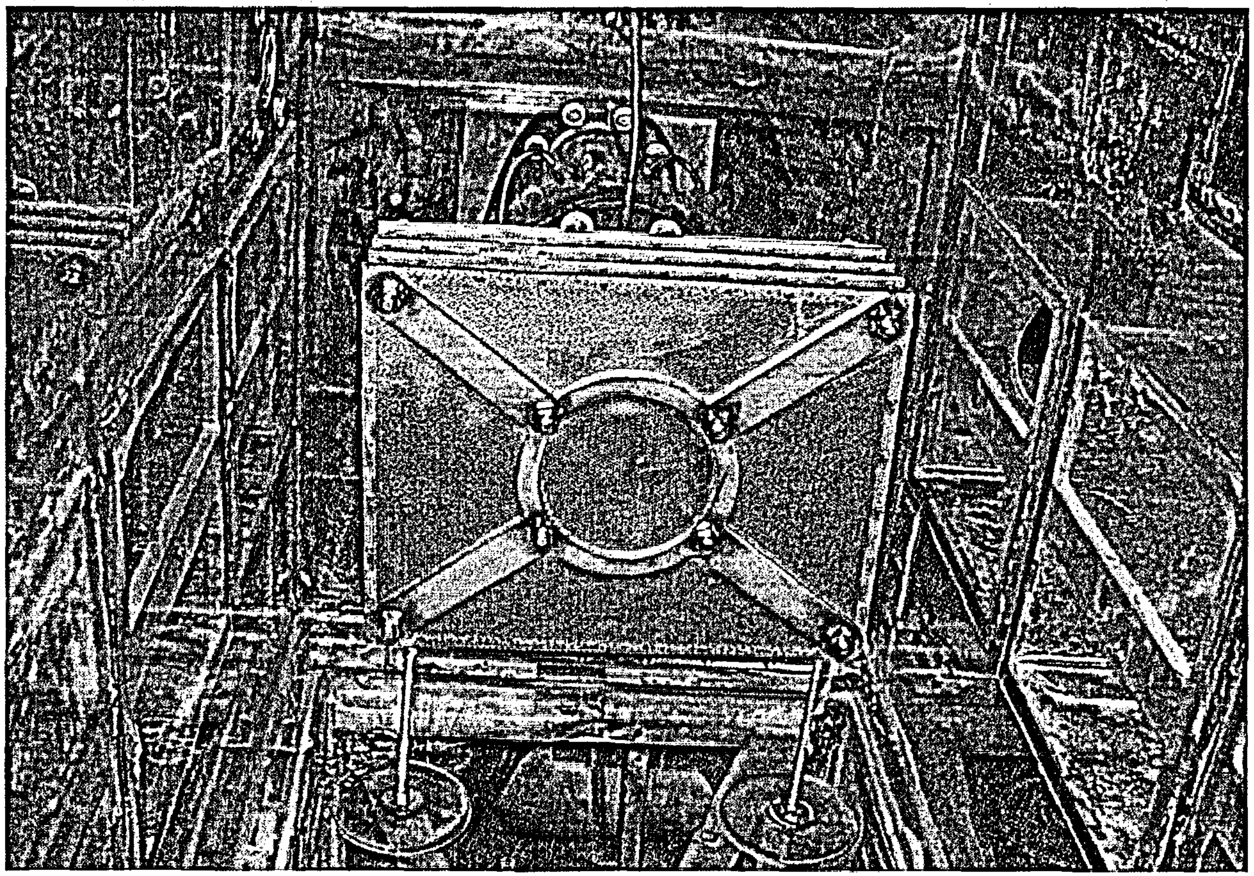
> Facilities Overview

- *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

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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

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DEBRIS INTRODUCTION METHODOLOGY

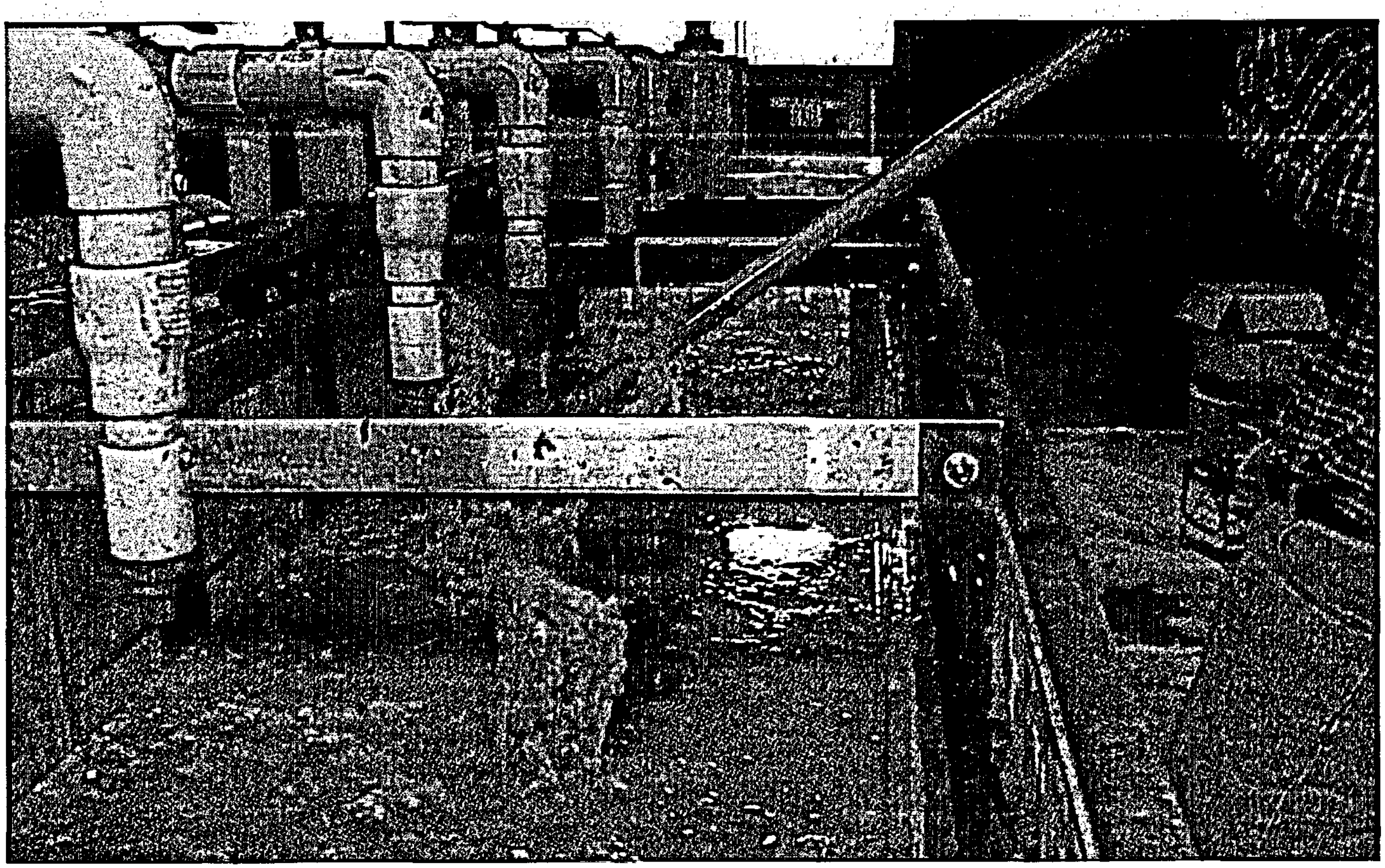
> Sequence

- 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**



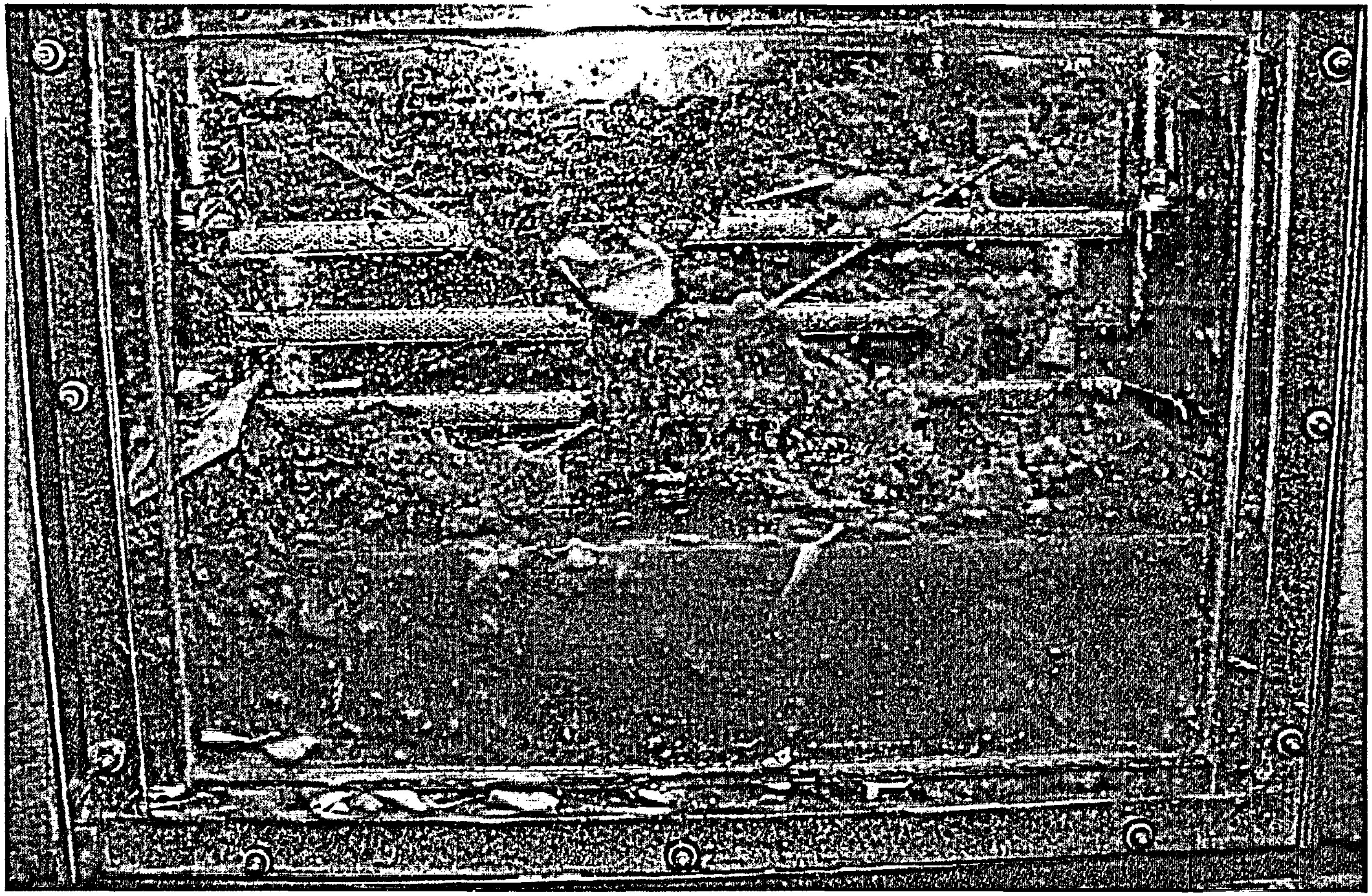
DEBRIS INTRODUCTION METHODOLOGY

> 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

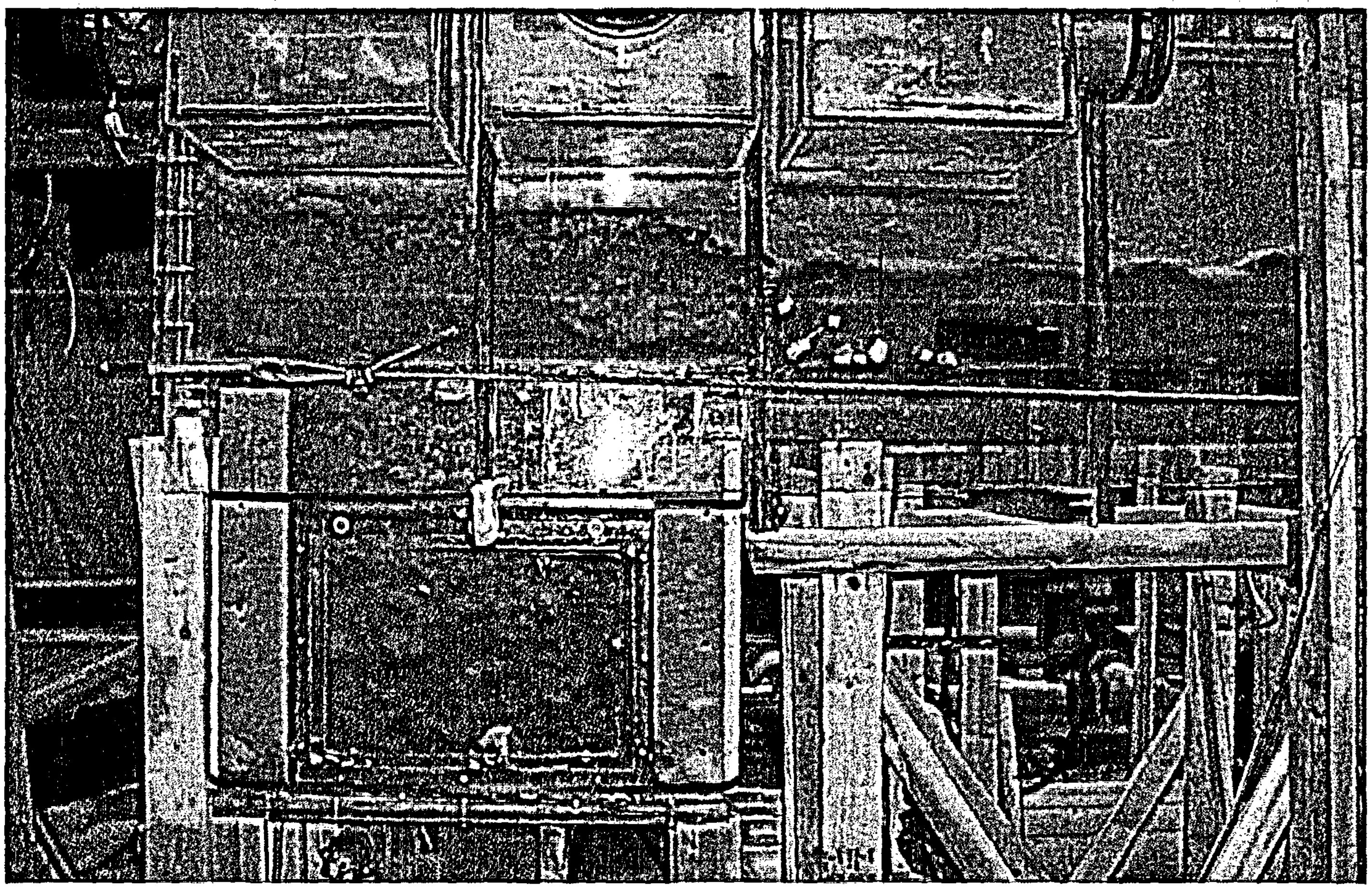
DEBRIS INTRODUCTION METHODOLOGY

Strainer mounted in a depressed pit



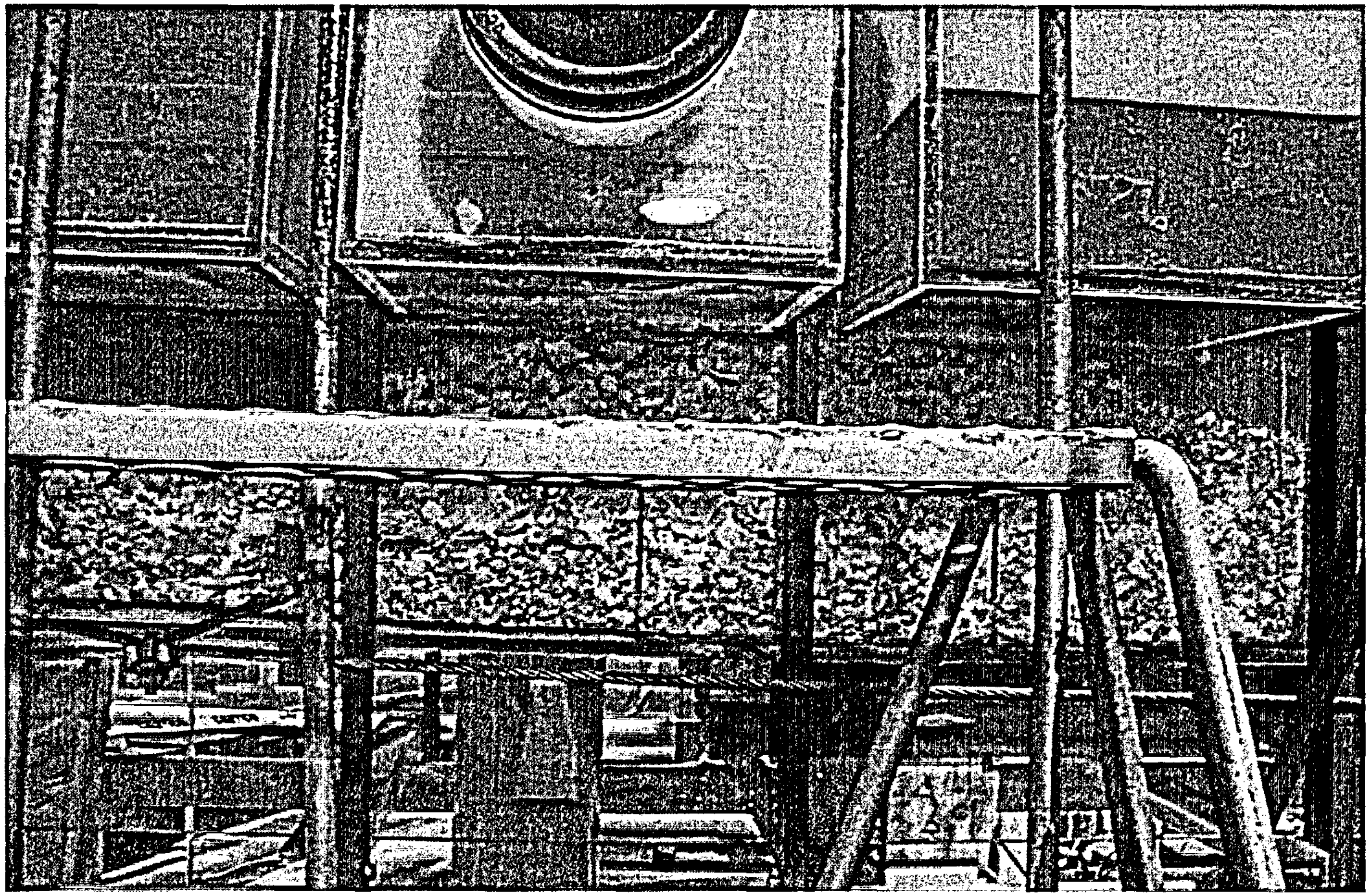
DEBRIS INTRODUCTION METHODOLOGY

Strainer mounted in a depressed pit buried in fibrous debris



DEBRIS INTRODUCTION METHODOLOGY

Strainer mounted horizontally buried in paint chips (no fiber)



TESTING SUMMARY

			[4]Flow Rate					Screen Area		Screen	Screen
Plant	Test	Test Description	Plant (gpm)	Design Test (gpm)	Circumscribed Test (gpm)	Debris Placement	Overhead Nozzles	Plant (ft^2)	Testing (ft^2)	Hole Φ (Inch)	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 (ft²)	Screen Area Testing (ft²)	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	Debris Head Loss: 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

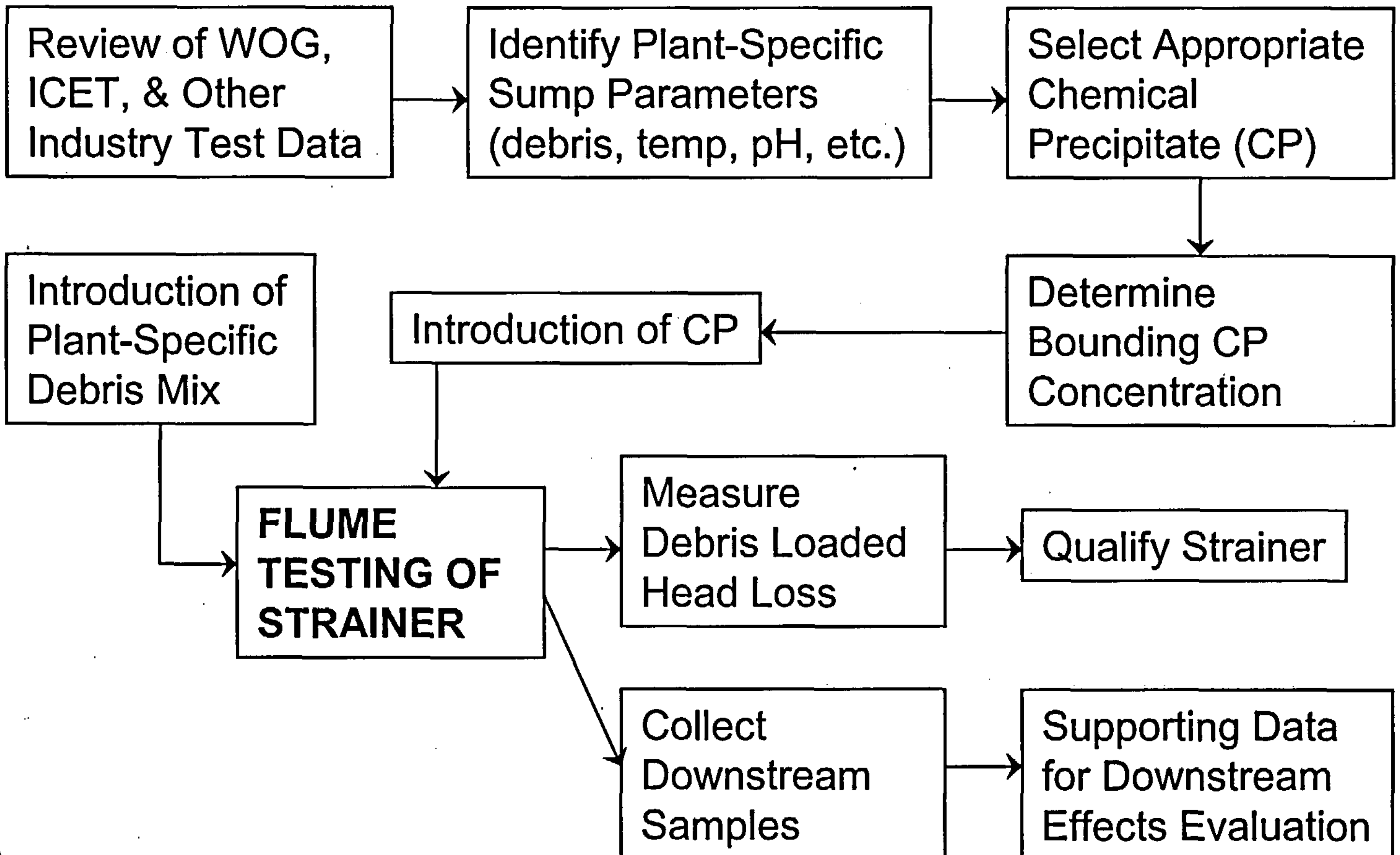
- Introduction of actual chemical byproducts in strainer tests using manufactured materials which represent chemical compounds expected to precipitate during accident conditions

> 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

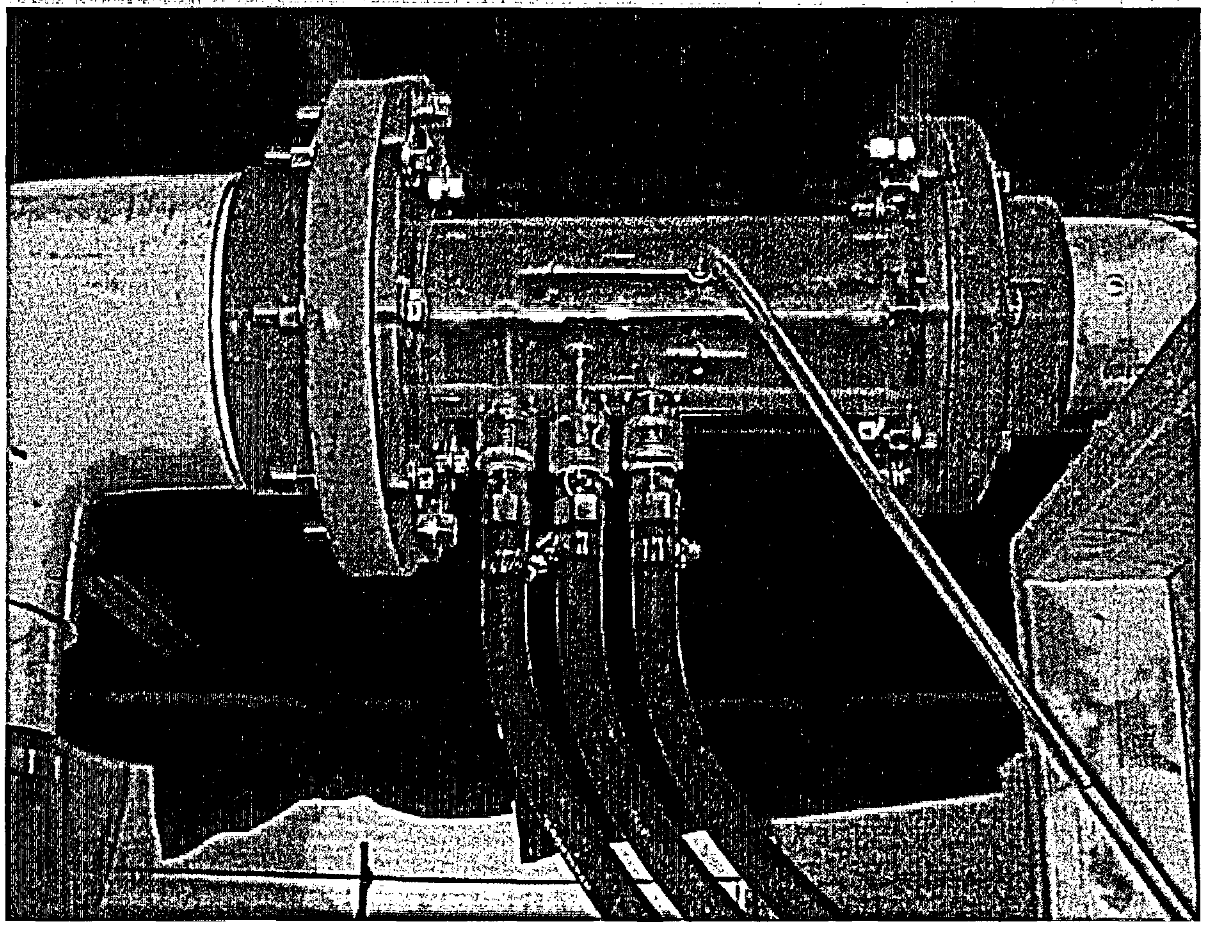
SCREEN PENETRATION TEST

> 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

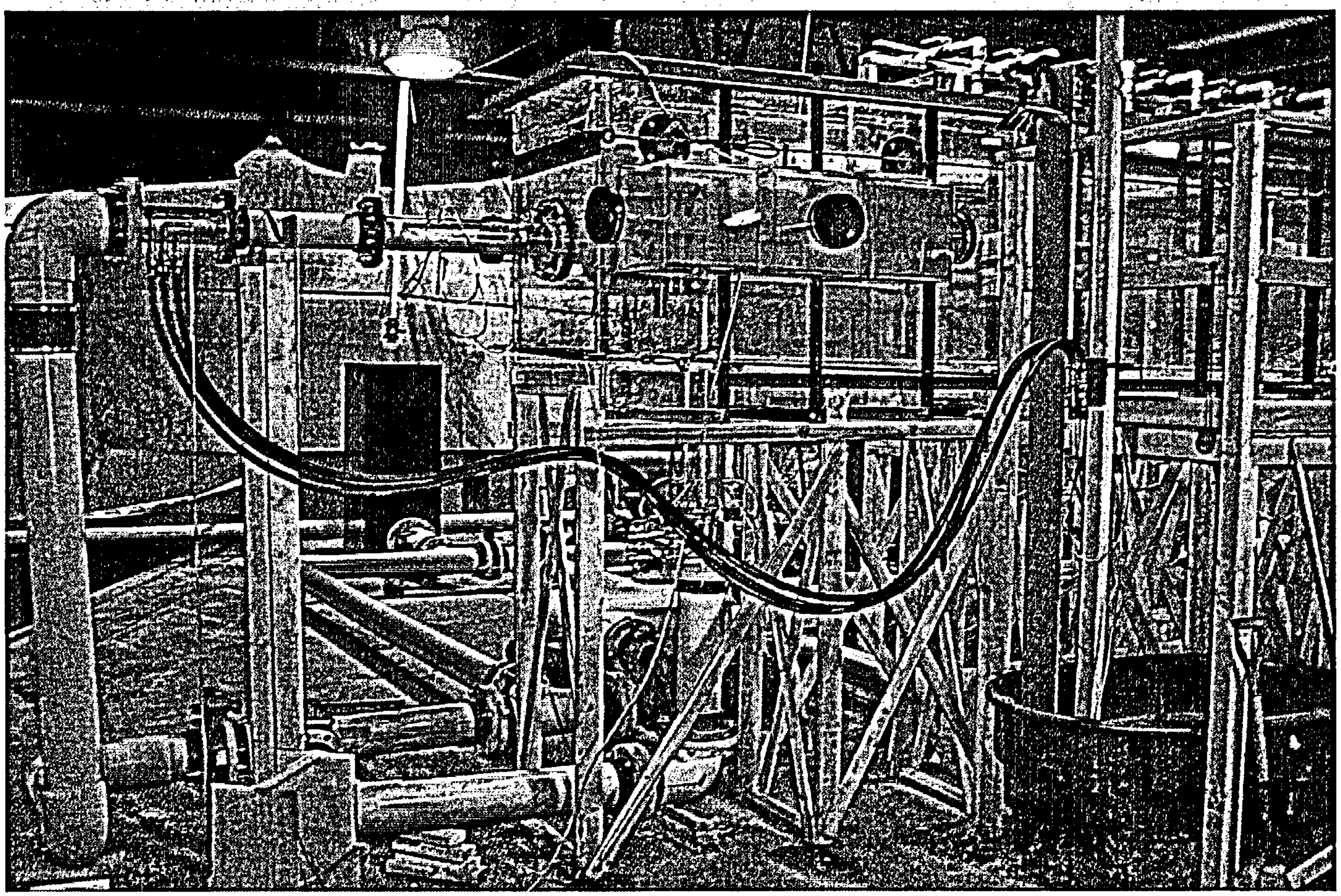
SCREEN PENETRATION TEST

Isokinetic Downstream Sampling Ports



SCREEN PENETRATION TEST

Isokinetic Downstream Sampling System



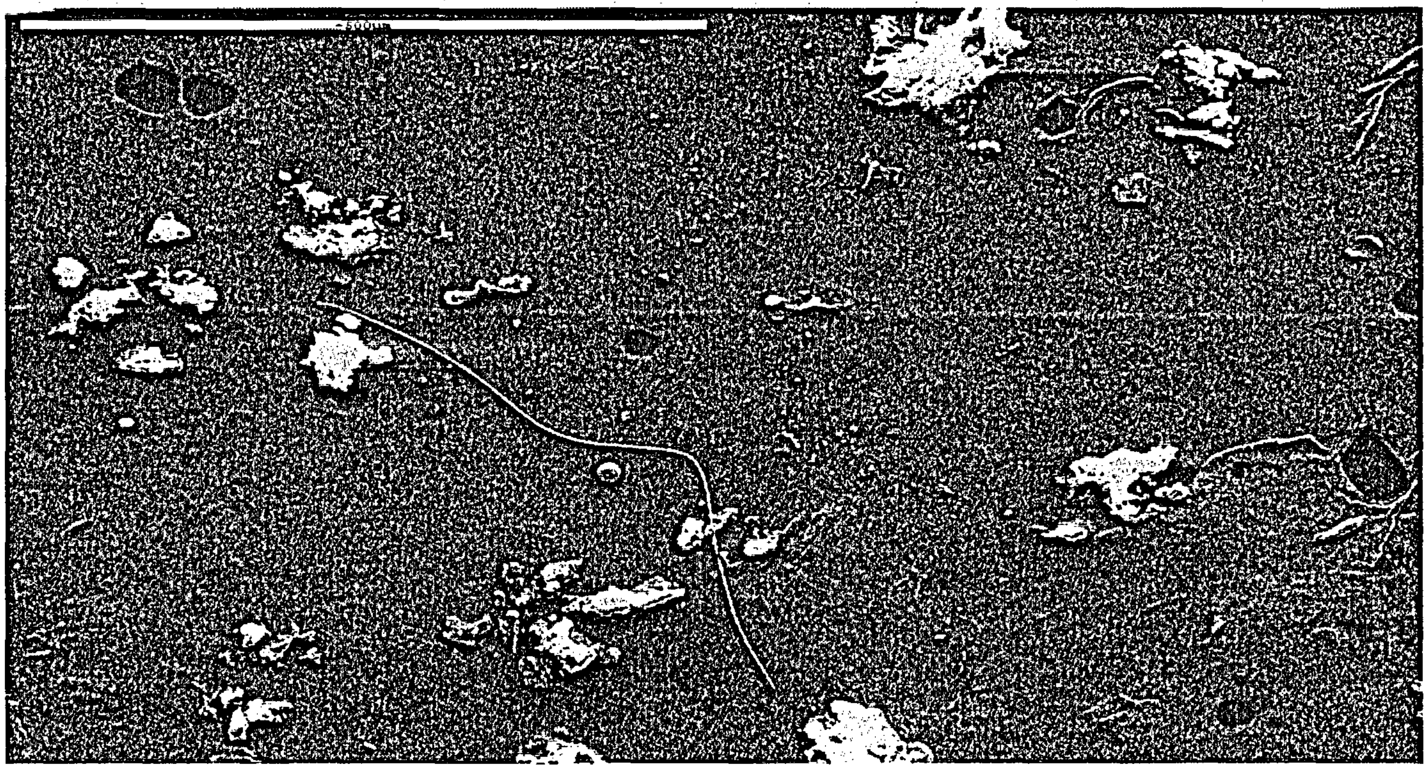
SCREEN PENETRATION TEST

> 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%

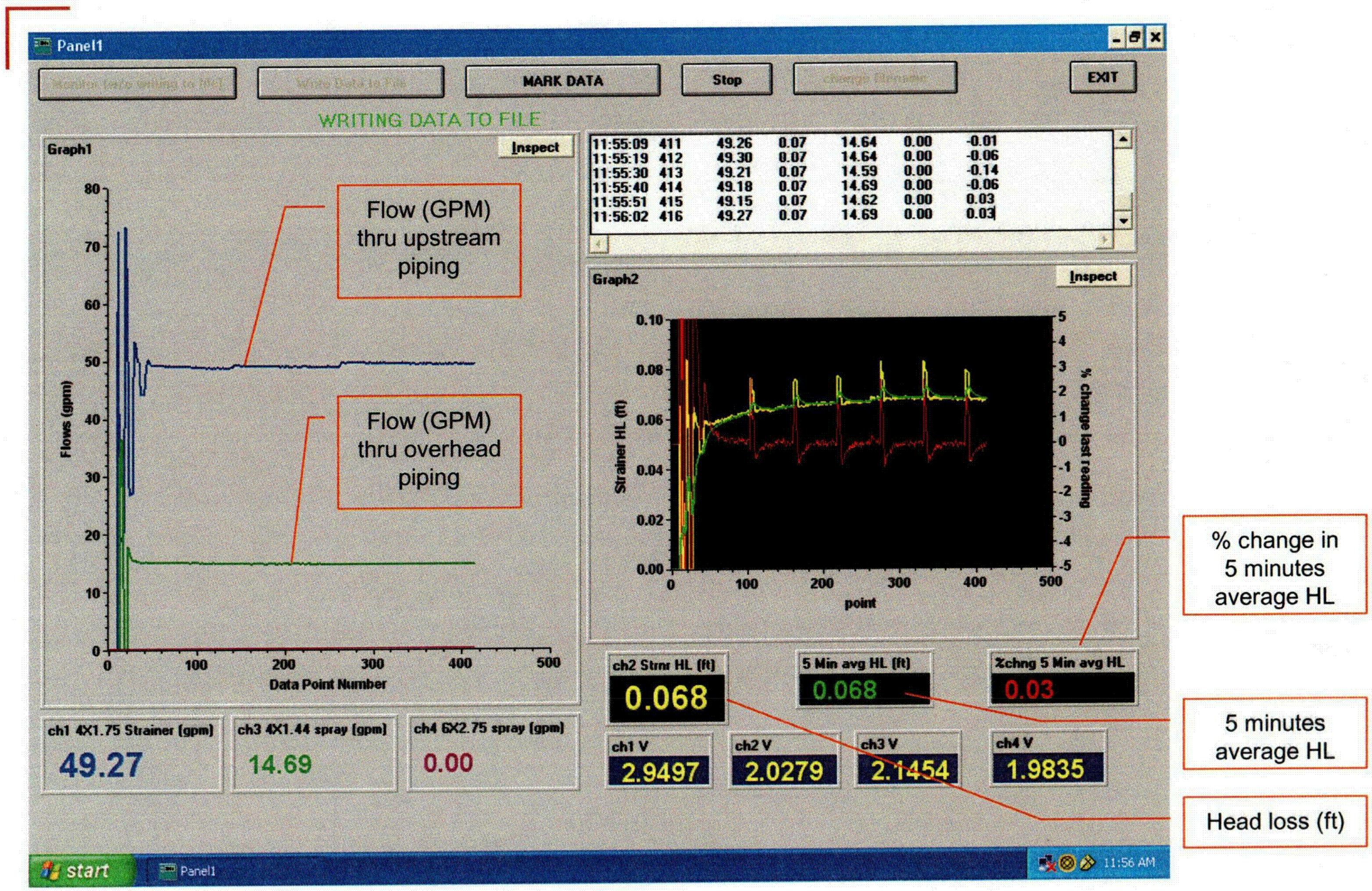
AND

- 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



REPLACEMENT STRAINERS

> Samples of replacement strainers

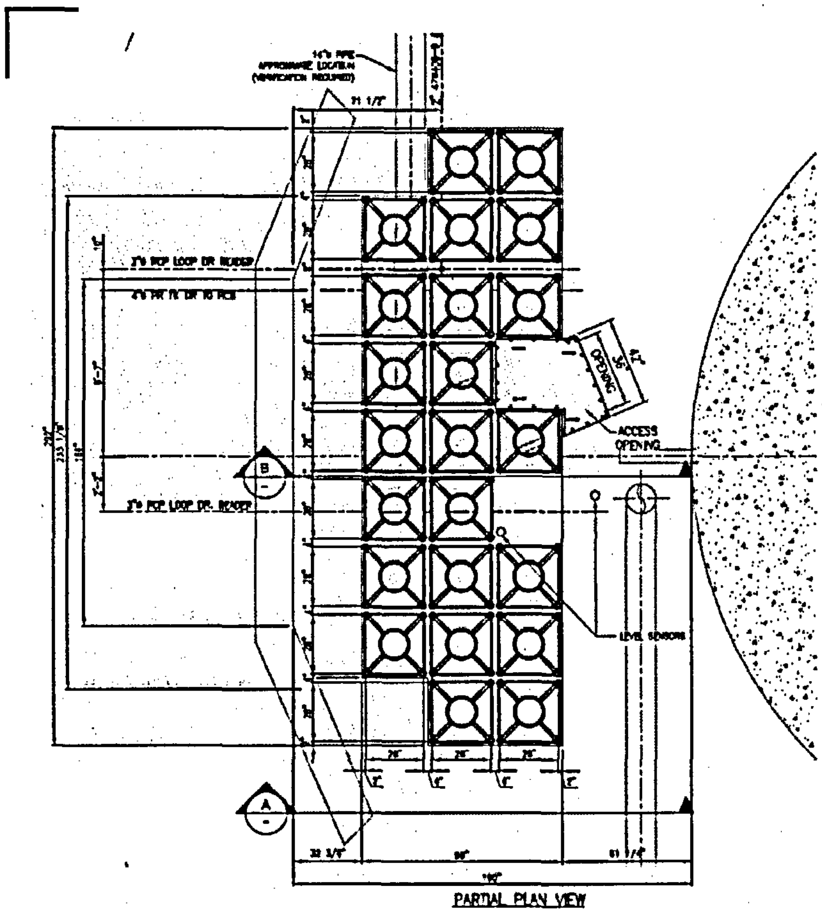
- Early conceptual designs
- Photographs of replacement strainers in the fabrication facility during trial fit-up

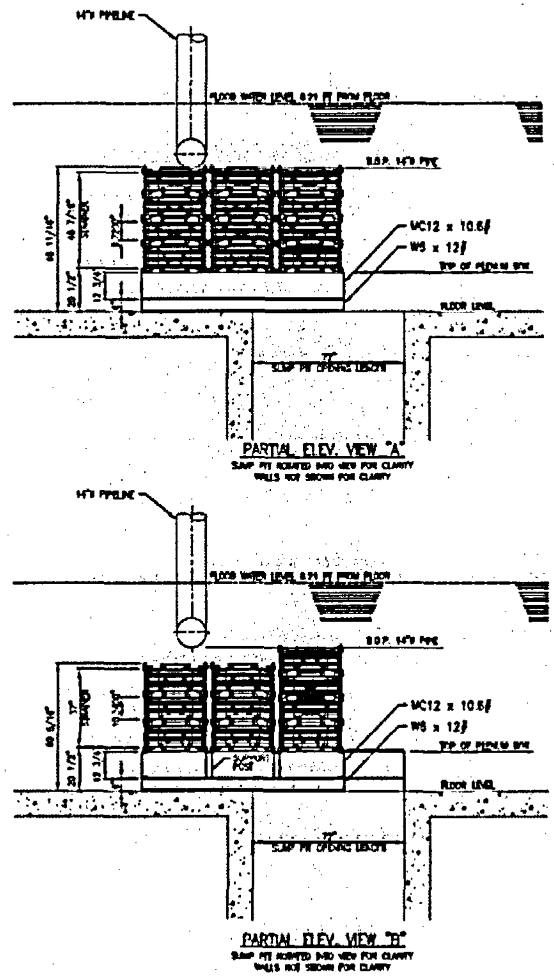
or

- Photographs of replacement strainers installed

REPLACEMENT STRAINERS

Plant V Early Replacement Strainer Design





REPLACEMENT STRAINERS

Plant V Replacement Strainers at the Fabrication Facility

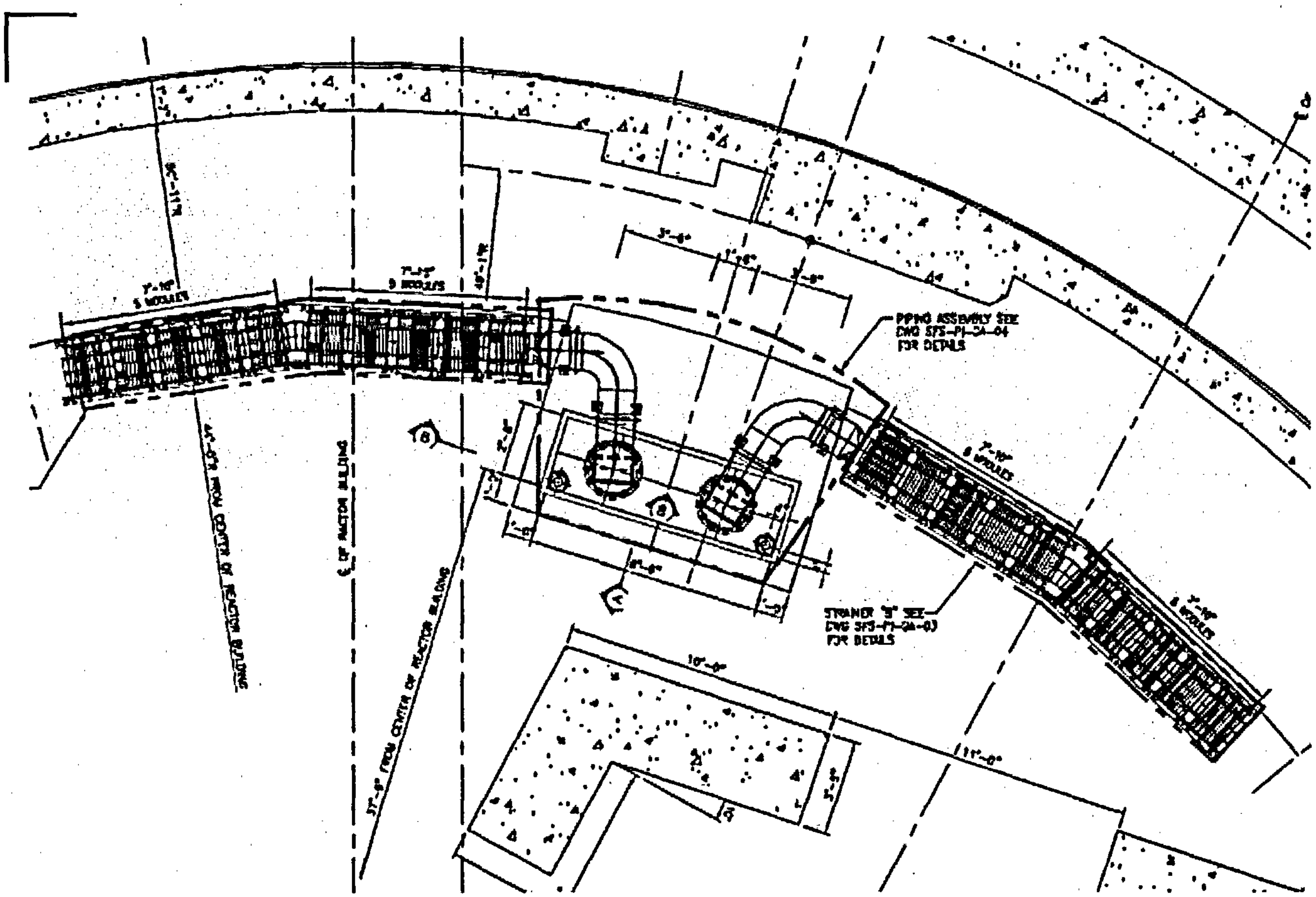
REPLACEMENT STRAINERS

Plant V Replacement Strainers at the Fabrication Facility

AREVA

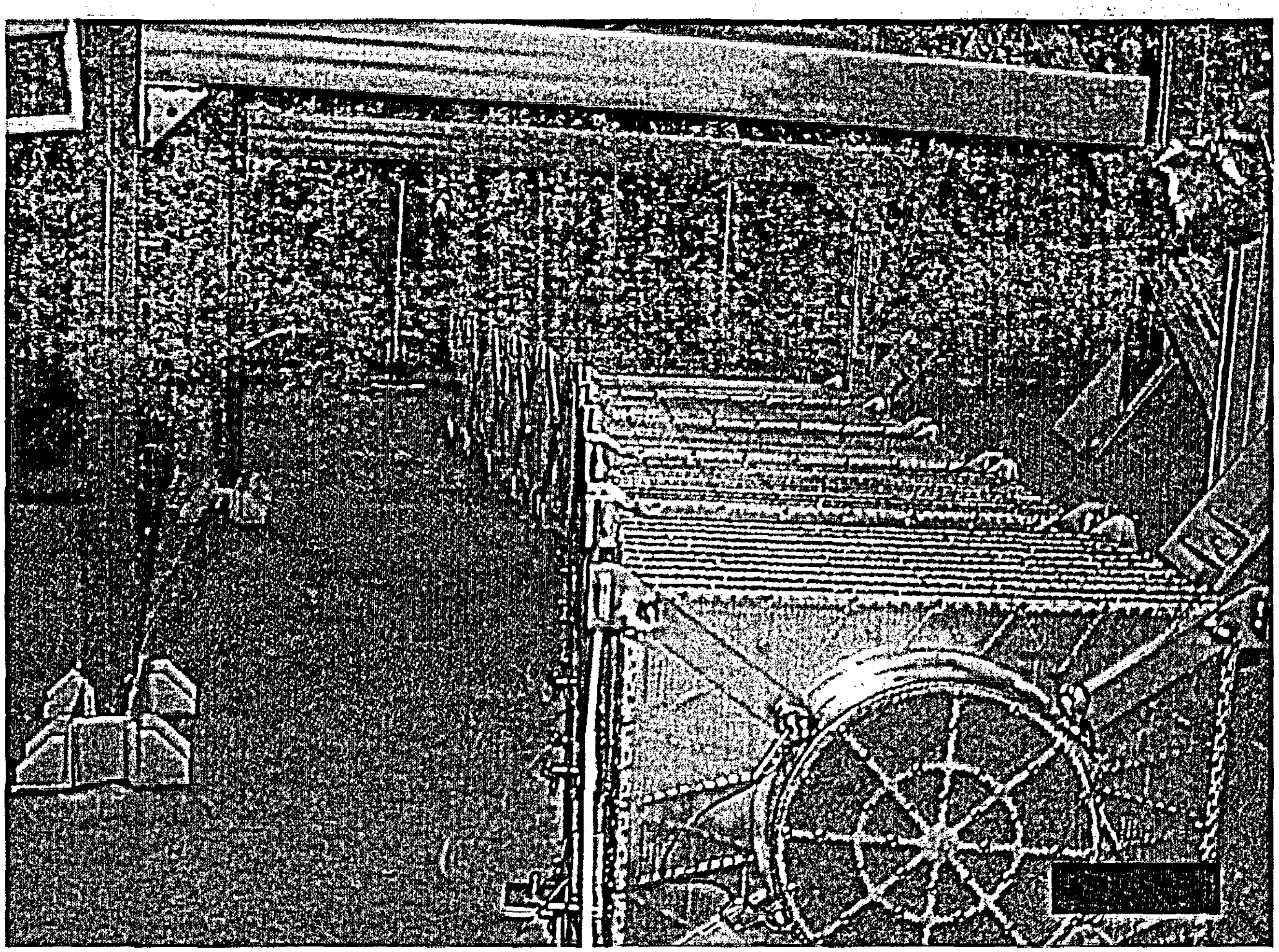
REPLACEMENT STRAINERS

Plant X Early Replacement Strainer Design



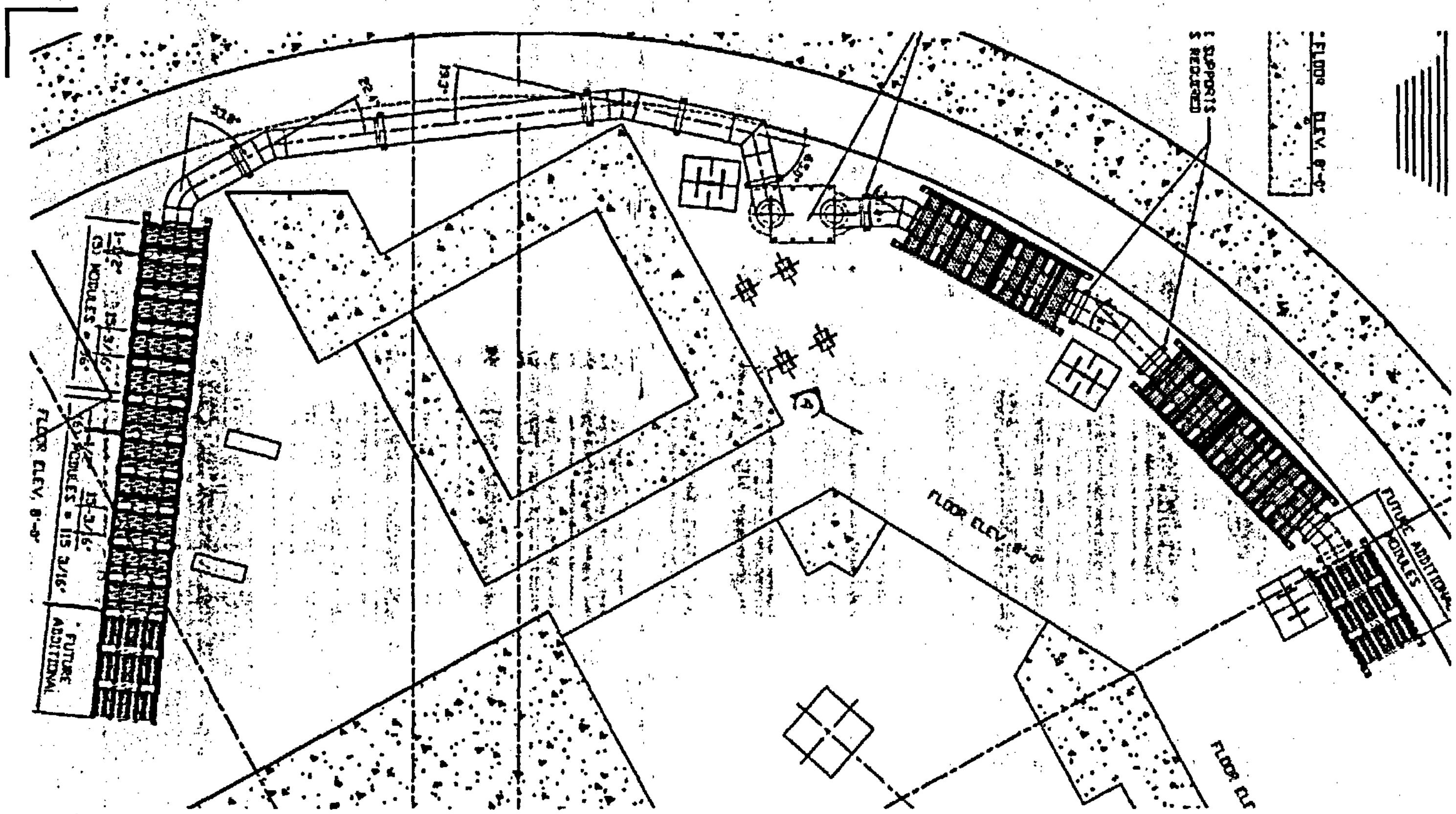
REPLACEMENT STRAINERS

Plant X Replacement Strainers Installed in the Plant



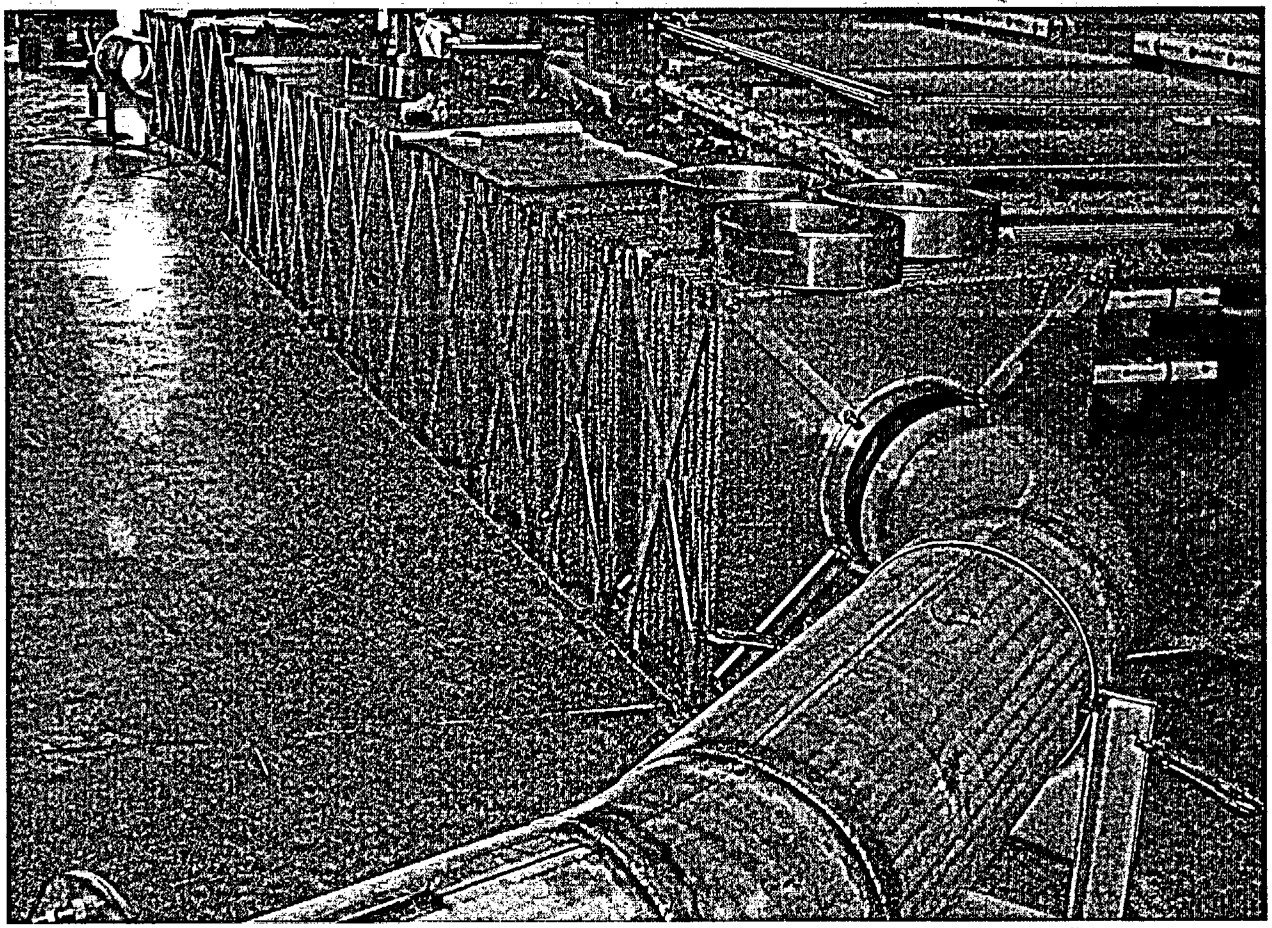
REPLACEMENT STRAINERS

Plant Y Early Replacement Strainer Design



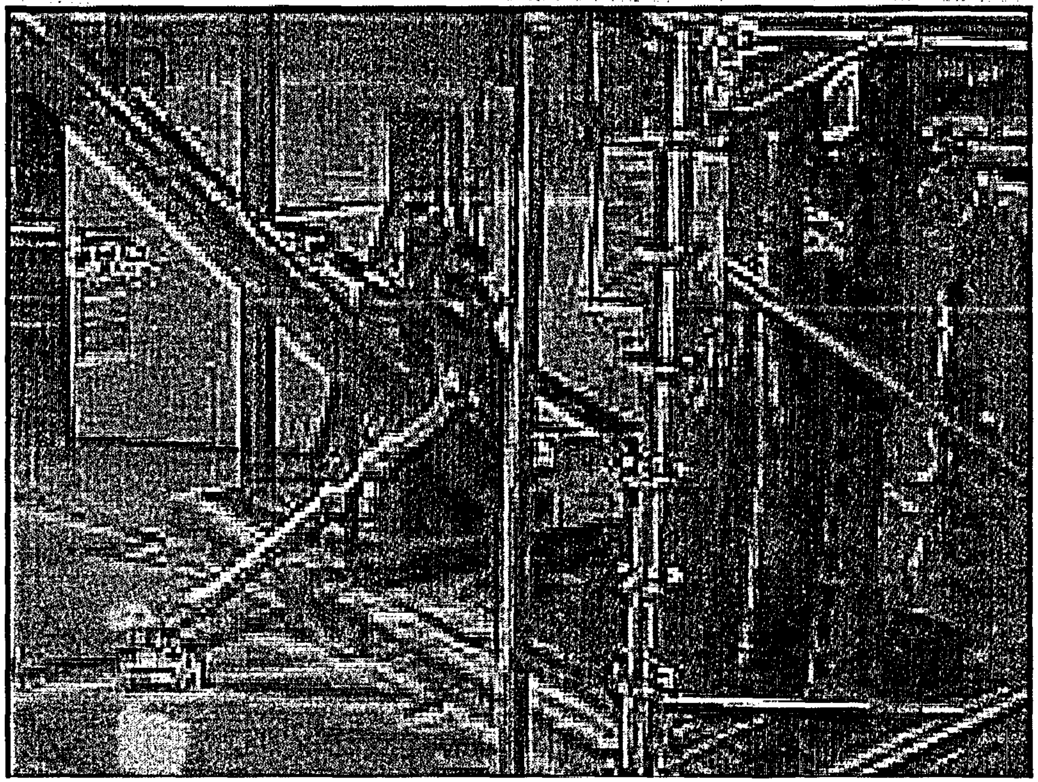
REPLACEMENT STRAINERS

Plant Y Replacement Strainers at the Fabrication Facility



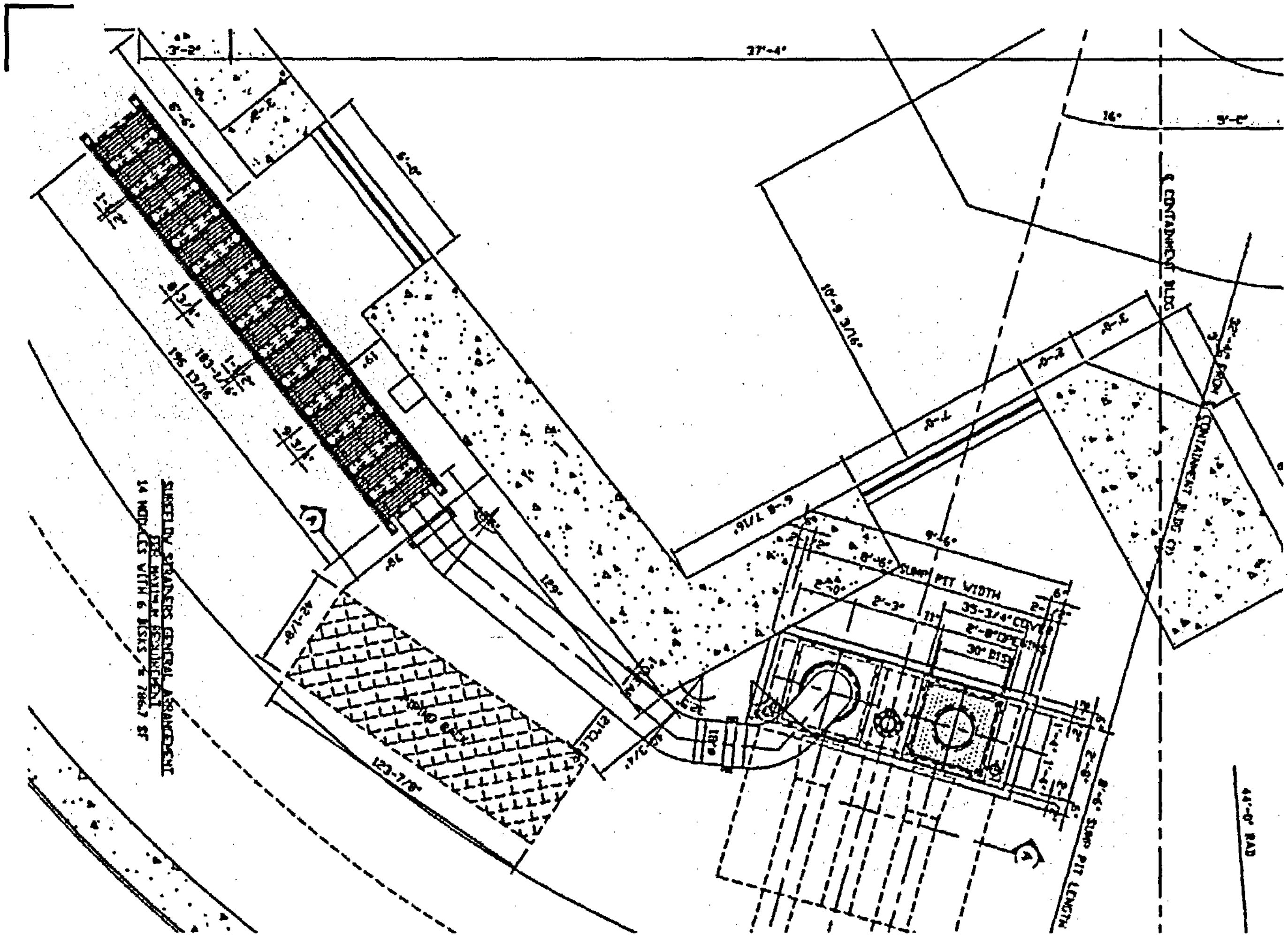
REPLACEMENT STRAINERS

Plant Z Original Strainers in the Plant



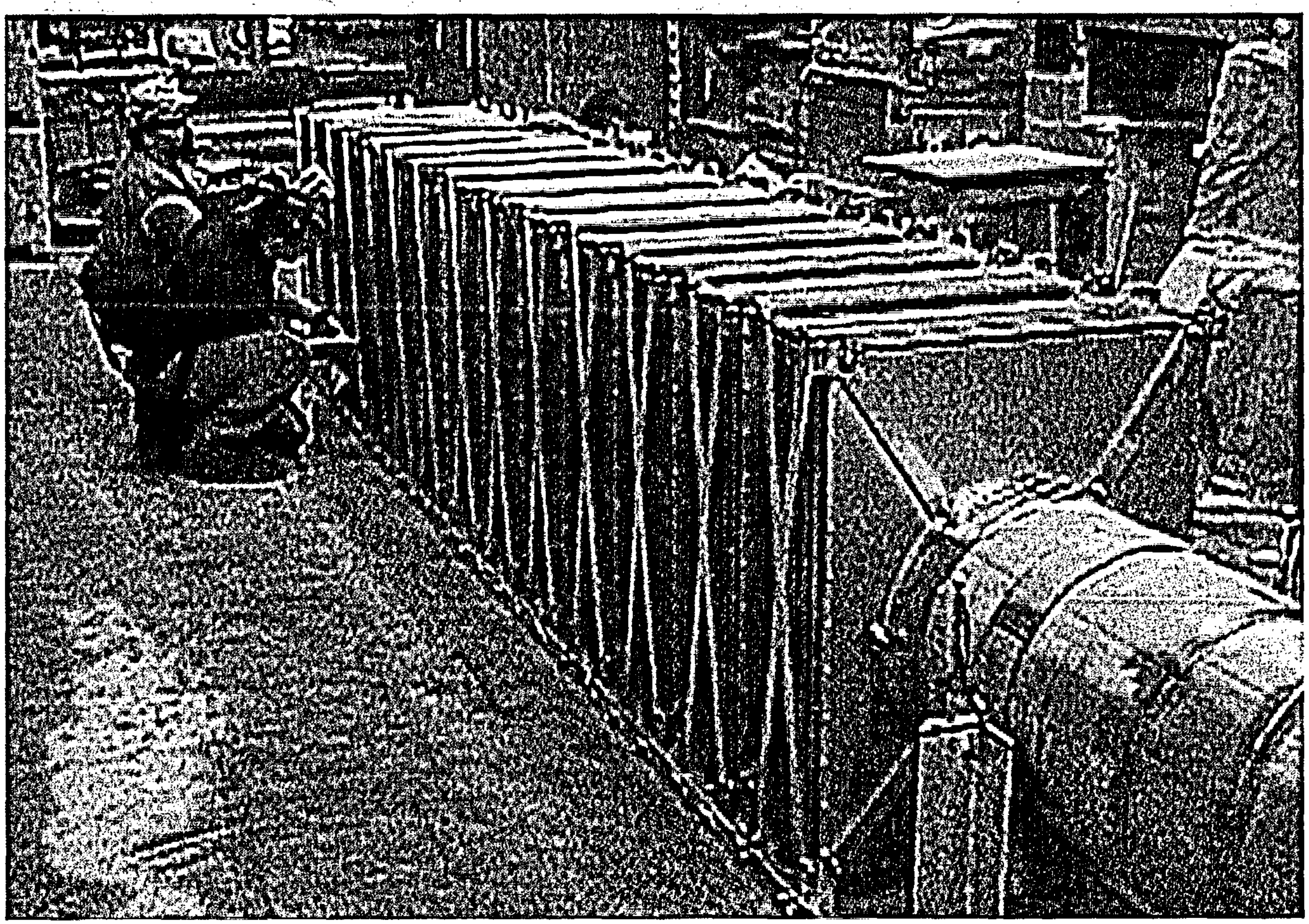
REPLACEMENT STRAINERS

Plant Z Early Replacement Strainer Design



REPLACEMENT STRAINERS

Plant Z Replacement Strainers at the Fabrication Facility



AREVA

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