AREVA

PCI PERFORMANCE CONTRACTING INC
ENGINEERED SYSTEMS

ALDEN
Solving Flow Problems Since 1894

NRC GSI-191 Vendor Testing Information

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Washington, DC
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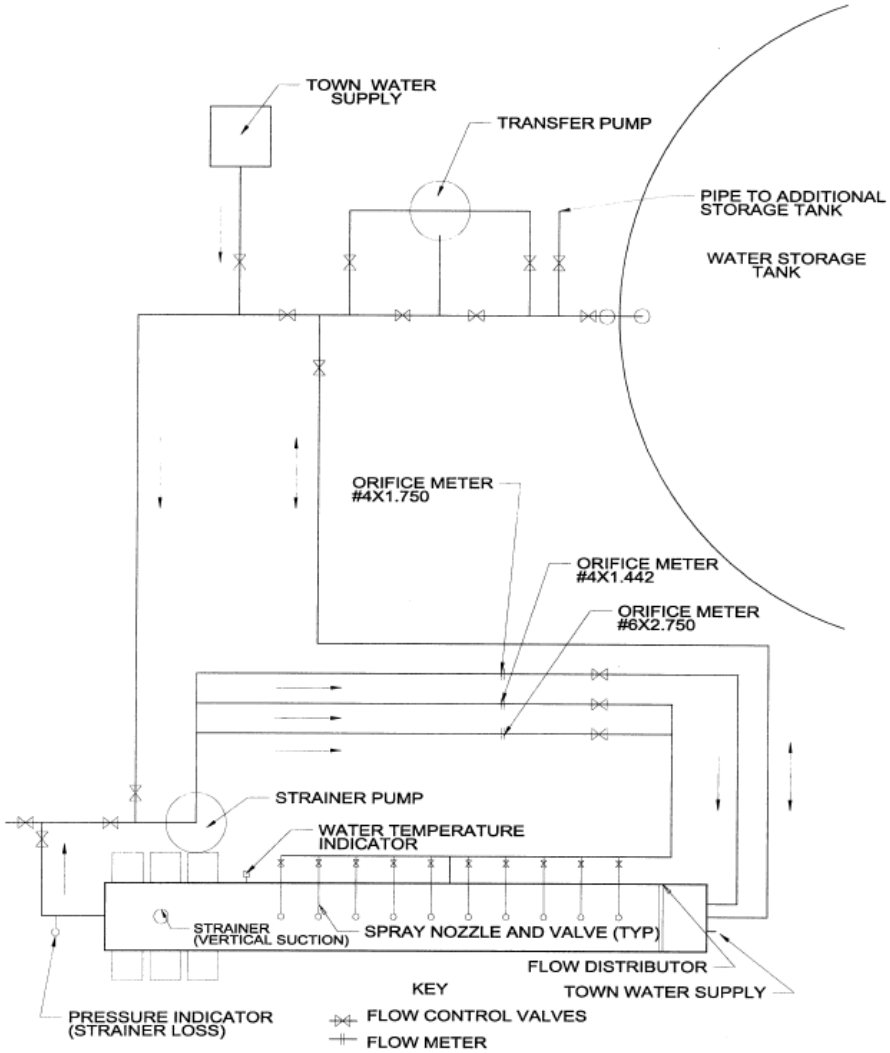
Agenda

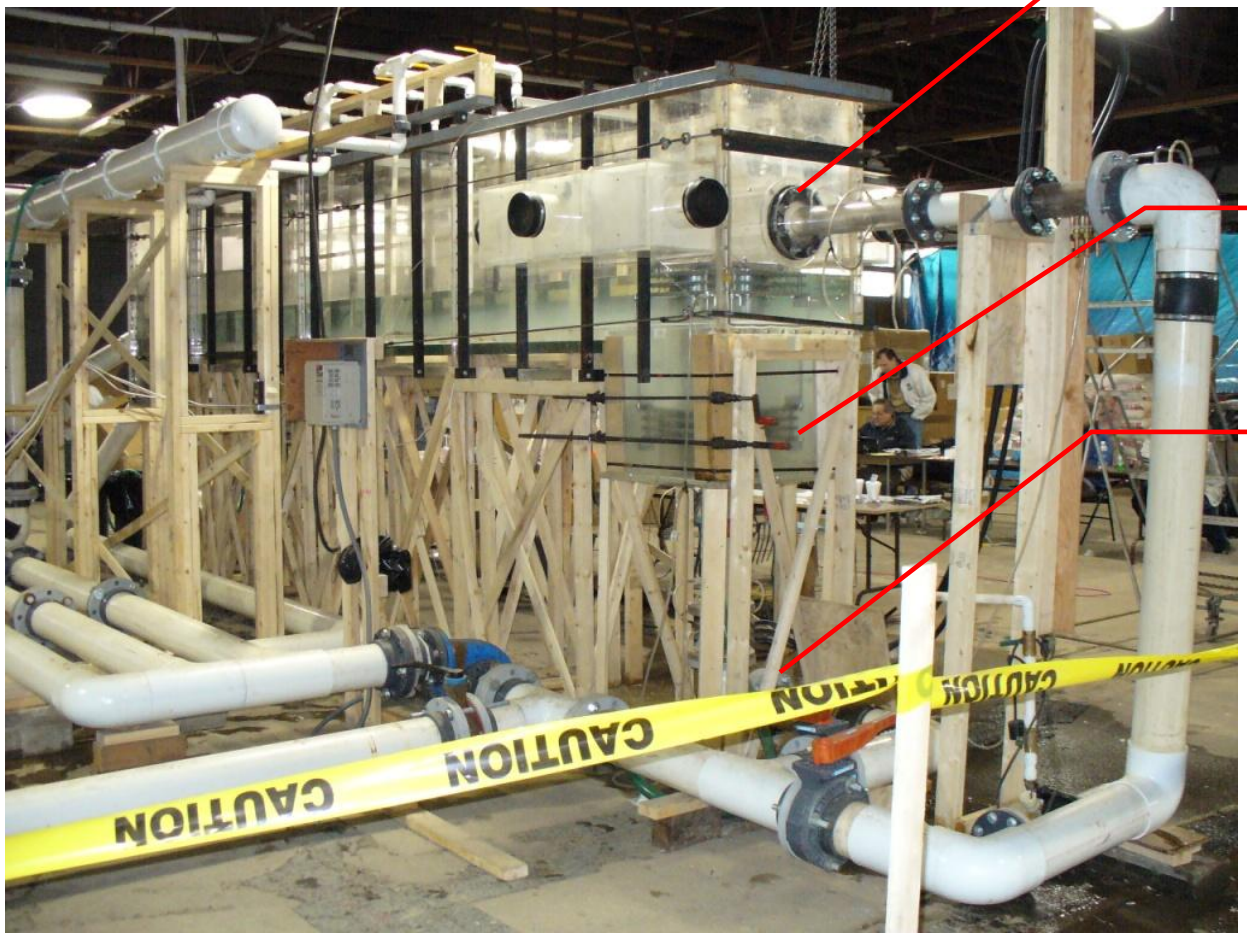
- General Topics
- Scaling Methodology
- Debris Preparation Methodology
- Debris Introduction Methodology
- Head Loss Due To Chemical Effects
- Screen Bypass Test
- Termination Criteria

General Topics
Facility Overview

- Flume Dimensions: 2.25ft wide x 3.25 ft deep x 20.9 ft long
- Calibrated Flow Capacity: 10 – 120 ft gpm at 30 ft head maximum
- Return flow through 10 overhead spray 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 12ft.
- Water temperature (range 40F-70F) recorded during tests



General Topics
Test Arrangement

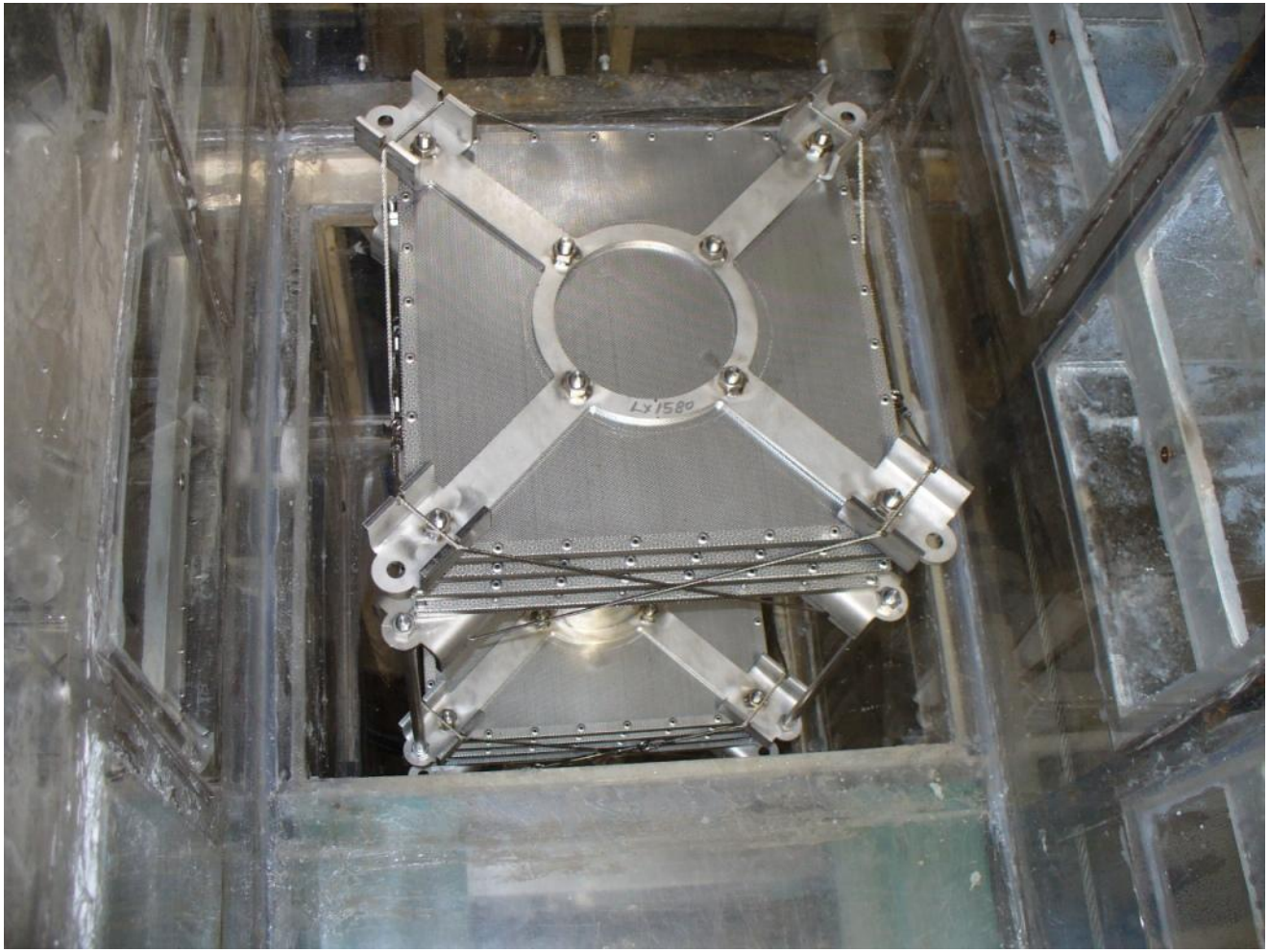


Horizontally Mounted Strainer Suction Piping

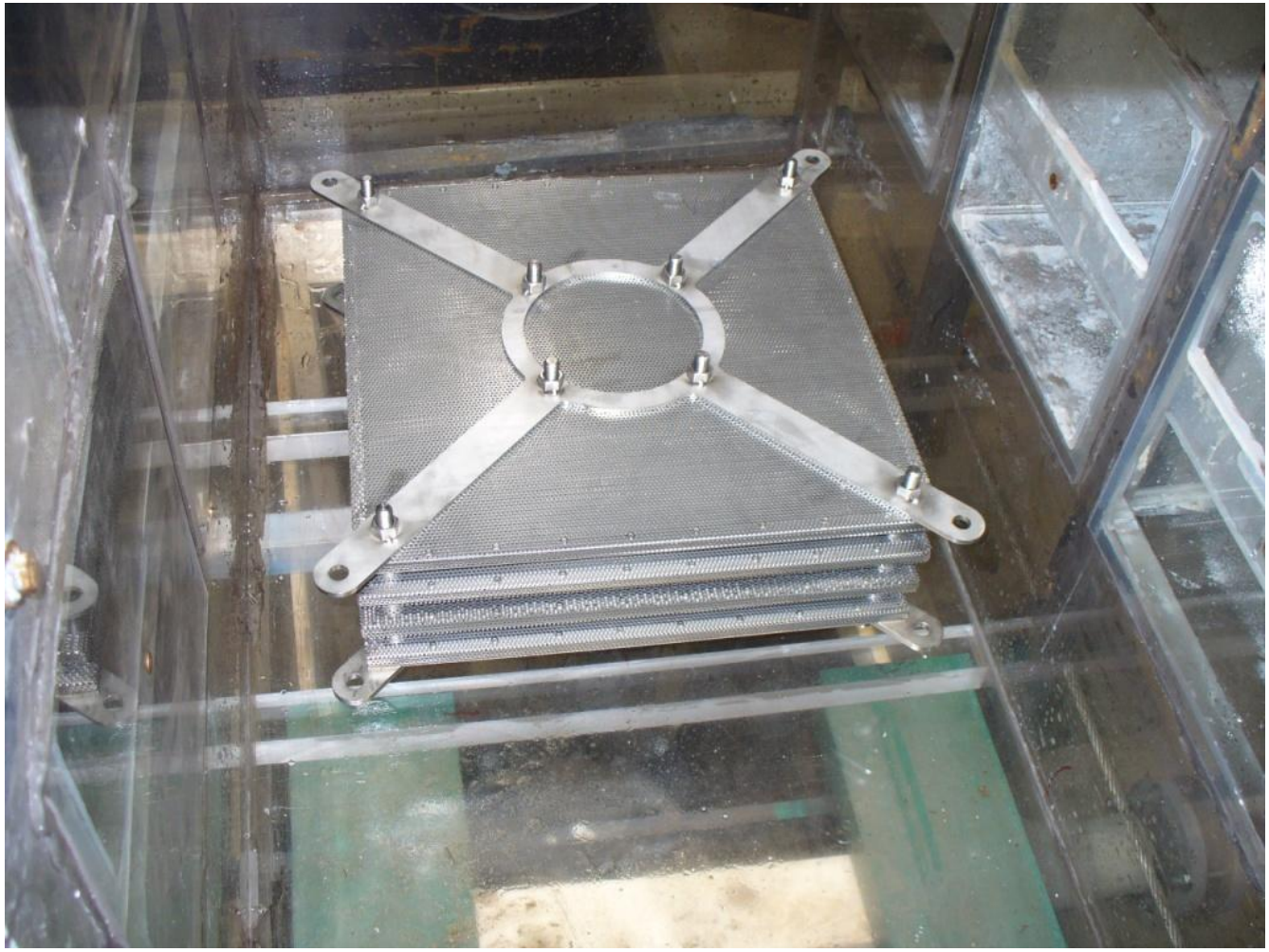
Depressed Pit

Vertically Mounted Strainer Suction Piping

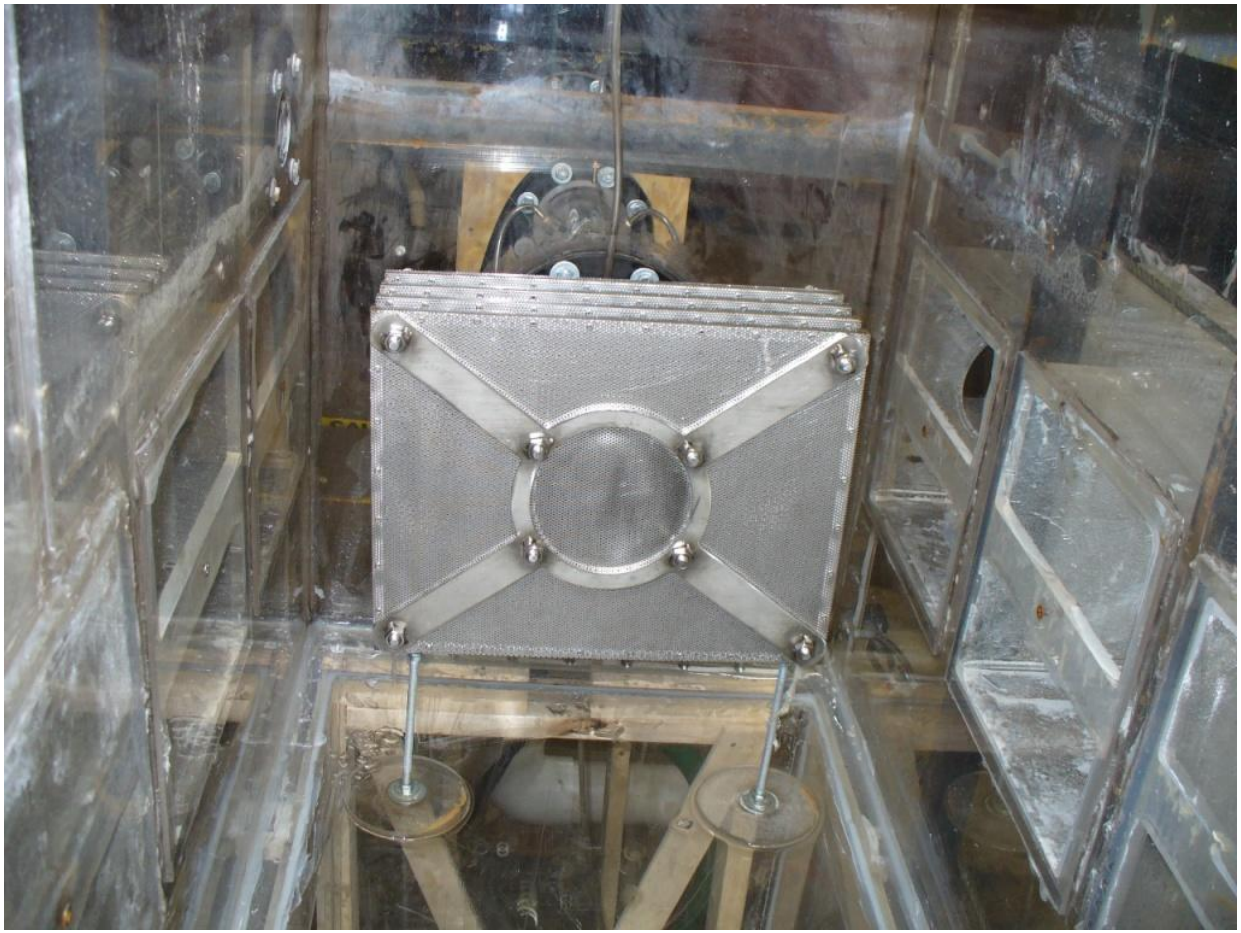
General Topics
Prototype Strainer Installed in Depressed Pit



General Topics
Prototype Strainer Installed Vertically



General Topics
Prototype Strainer Installed Horizontally



General Topics
Strainer Design Parameters

- *Plant design flow rate range: 2,200 –19,100 gpm*
- *Test flow rate range: 15 – 120 gpm*
- *Approach velocity range: 0.0033 – 0.0272 ft/s*
- *Total Plant screen area range: 770 – 7,500 ft^2*
- *Strainer hole diameter range: 0.045 – 0.095 in*

General Topics
Listing of Licensees

Two (2) units fabricated and delivered to date

Twelve (12) units in progress for U.S. PWRs

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

Design Basis Debris Testing is Complete

General Topics
Key Observations

Important parameters affecting head loss:

- **Approach velocity at the screen surface**
- **Debris mix (quantity & type)**
- **Use of overhead spray (keeping fine debris in suspension)**
- **Debris preparation**
- **Submergence**

Head loss is highly plant specific

General Topics
Key Observations

- **RMI, tags & labels, and paint chips do not collect on the screen**

- **While in general measured head losses are much less than predicted, some test combinations resulted in head losses near NUREG/CR-6224 predictions**

Scaling Methodology Geometry

- Test protocol has evolved over the course of testing (debris placement, use of overhead spray nozzles, etc.) with no significant maximum head loss differences
- Strainer preliminary screen sized per NUREG/CR-6224. Strainer final sizing based on available plant footprint, NPSH margins available combined with testing results
- Actual plant submergence used in test
- Test flow condition reflected plant condition at or near the strainer. Debris placement varied to remove flume transport uncertainty.

Scaling Methodology Temperature

- **Actual water temperature recorded during test**
- **Measured head loss in debris test adjusted to the design basis temperature based the corresponding viscosities**

Scaling Methodology
Modular Strainer Setup

- **Scale fraction for test debris & test flow is the ratio of test strainer area to plant strainer area**
- **Sensitivity tests at determined circumscribed flow rates (in high fiber test conditions) by increasing test flow**

Debris Preparation Methodology

- ***Debris weighed dry in buckets/large trashcans***
- ***Debris is mixed with water using a paint mixer powered by an electric-drill***
- ***Surrogate material used based on size, shape, & density equivalent to actual material***

Debris Introduction Methodology Sequence

- Debris introduction into flume in following order

  1. RMI
  2. Particulate
  3. Fibrous
  4. Latent Fiber
  5. Chemical

- Manual mixing performed prior to start of test

- Overhead sprays provided mixing energy during test

Manual Mixing Prior to Pump Start

Debris Introduction Methodology Location

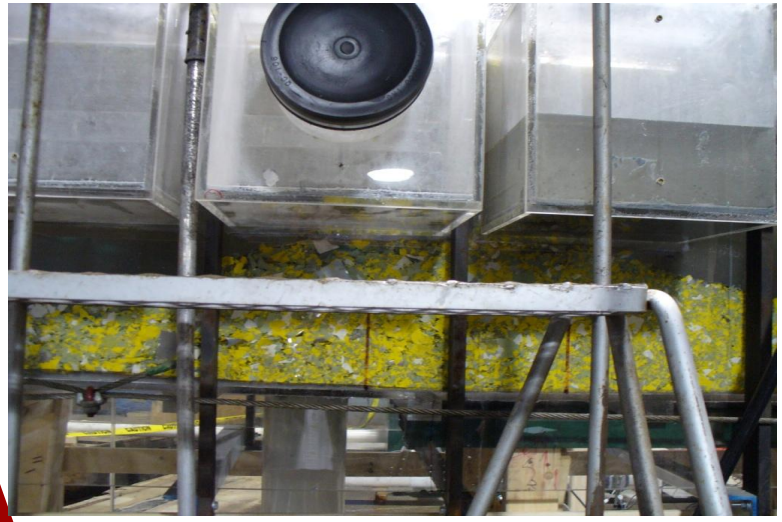
Debris introduced:

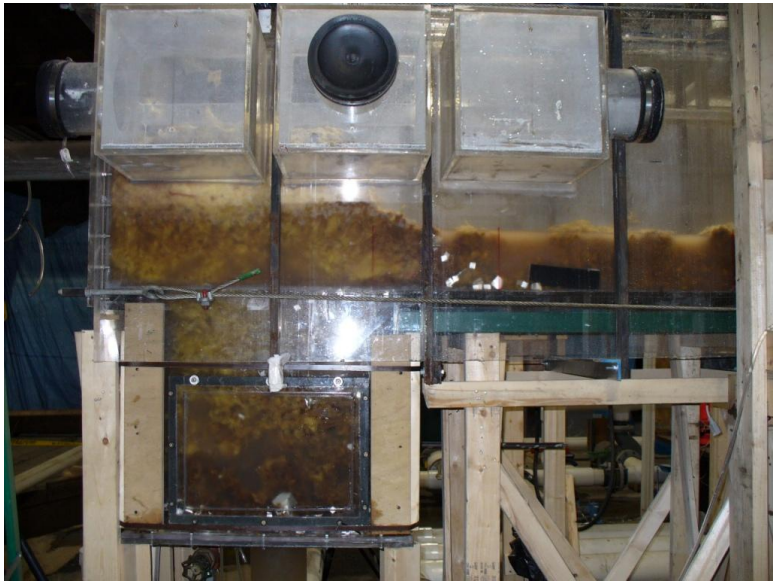
- ***Throughout the flume***
- ***1-3 feet upstream of the strainer***
- ***Directly on top of the strainer***

Timing of max. HL affected by debris placement

Total HL with similar debris but varied placement similar

Debris Introduction Methodology
Debris Location

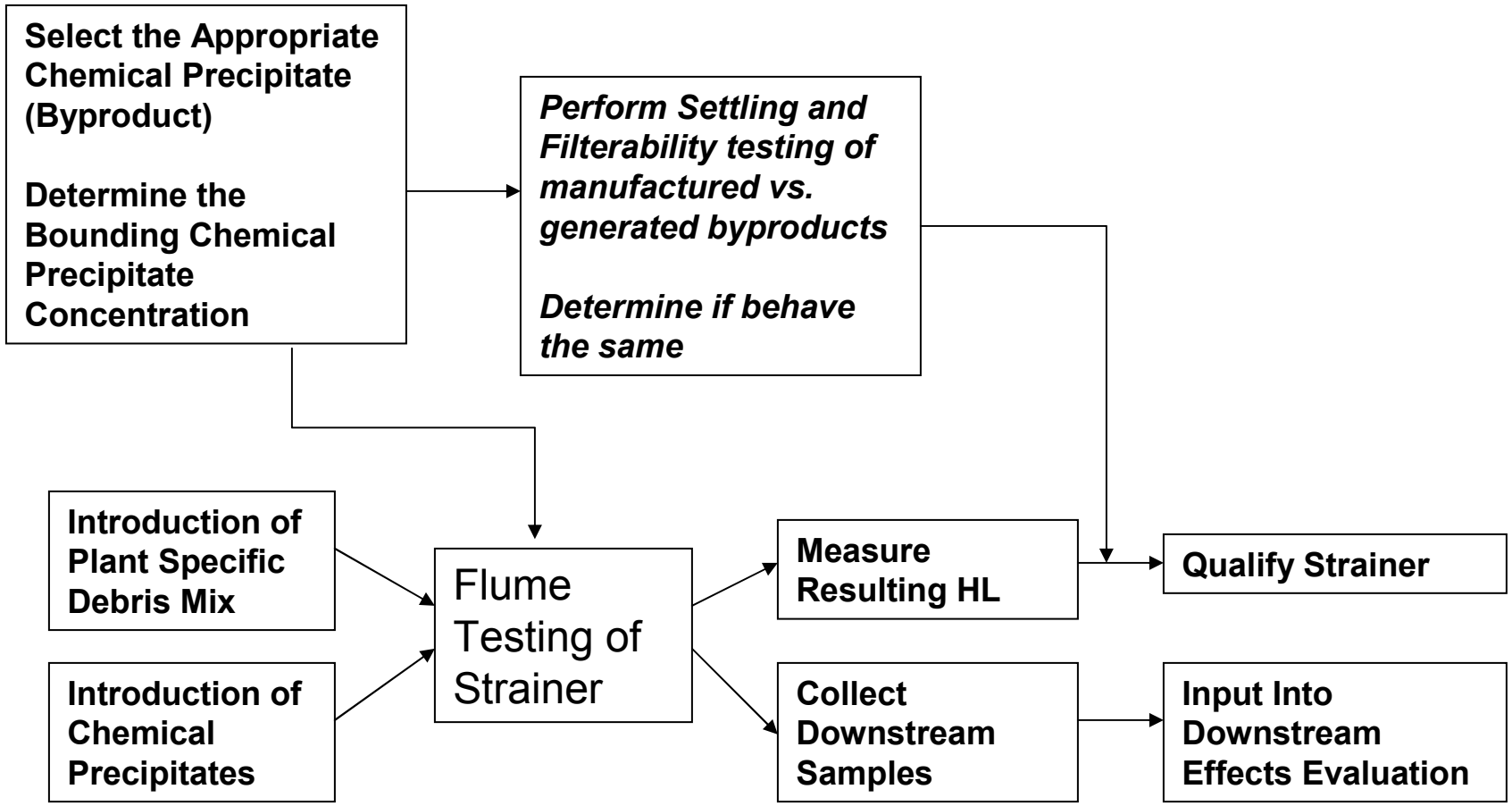




Chemical Effects

- Chemical debris testing performed in accordance with the criteria set in WCAP-16530-NP
- Introduction of chemical precipitants in strainer tests using actual chemical byproducts (Aluminum hydroxide, Sodium Aluminum Silicate, Calcium Carbonate, TriCalcium Phosphate)
- Chemical additive varied by plant based on moderator and insulation type
- On going chemical debris settling and filterability testing to show similar behavior of manufactured vs. generated materials

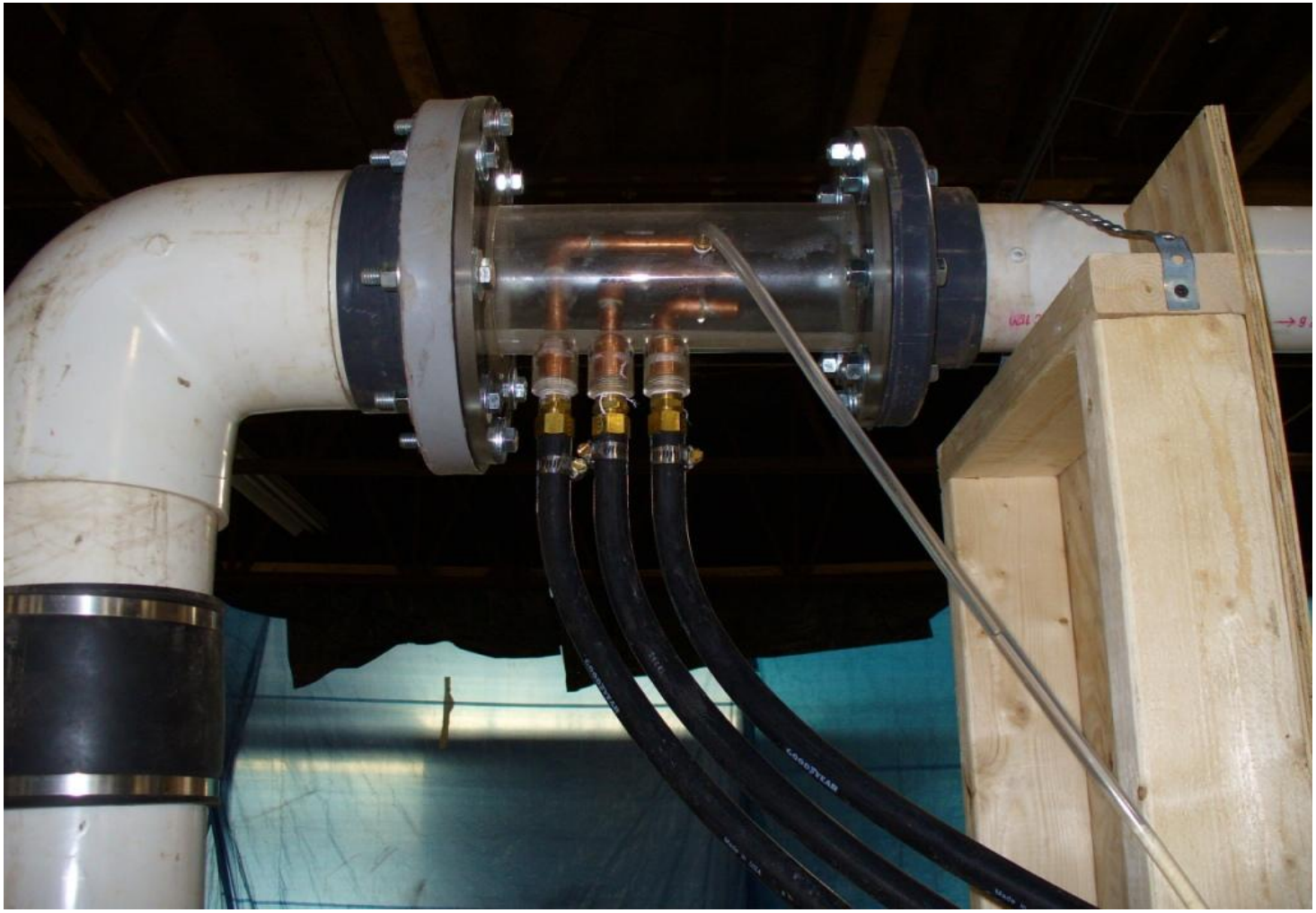
Integrated Chemical Effects



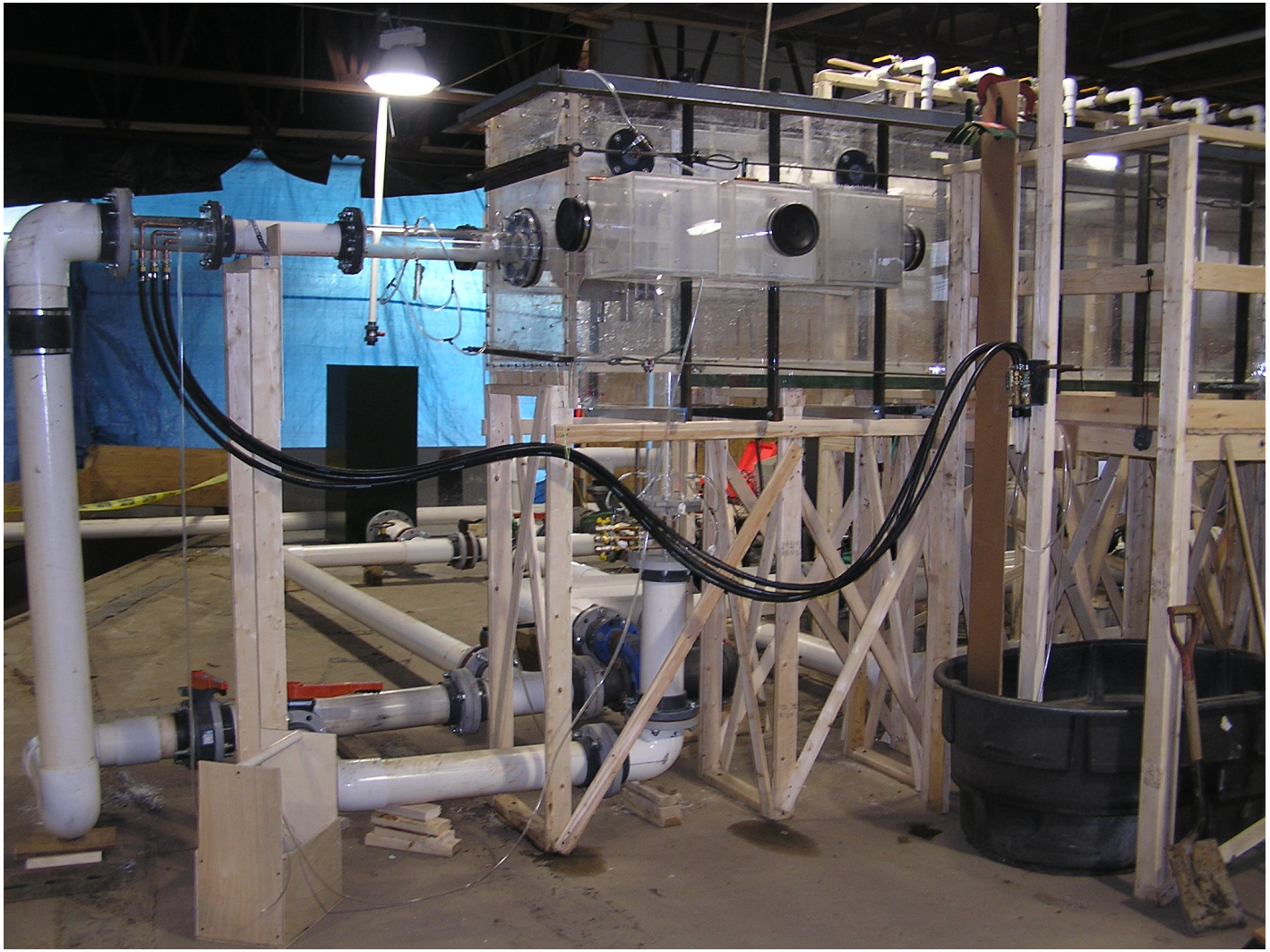
Screen Bypass Test

- **Three (3) isokinetic sampling ports located in the 6 inch strainer 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 over the first hour of testing.**
- ***Samples analyzed via Scanning-Electron-Microscopy (SEM)***
- ***Calculation to quantify the amounts of debris bypassed using SEM results as input***

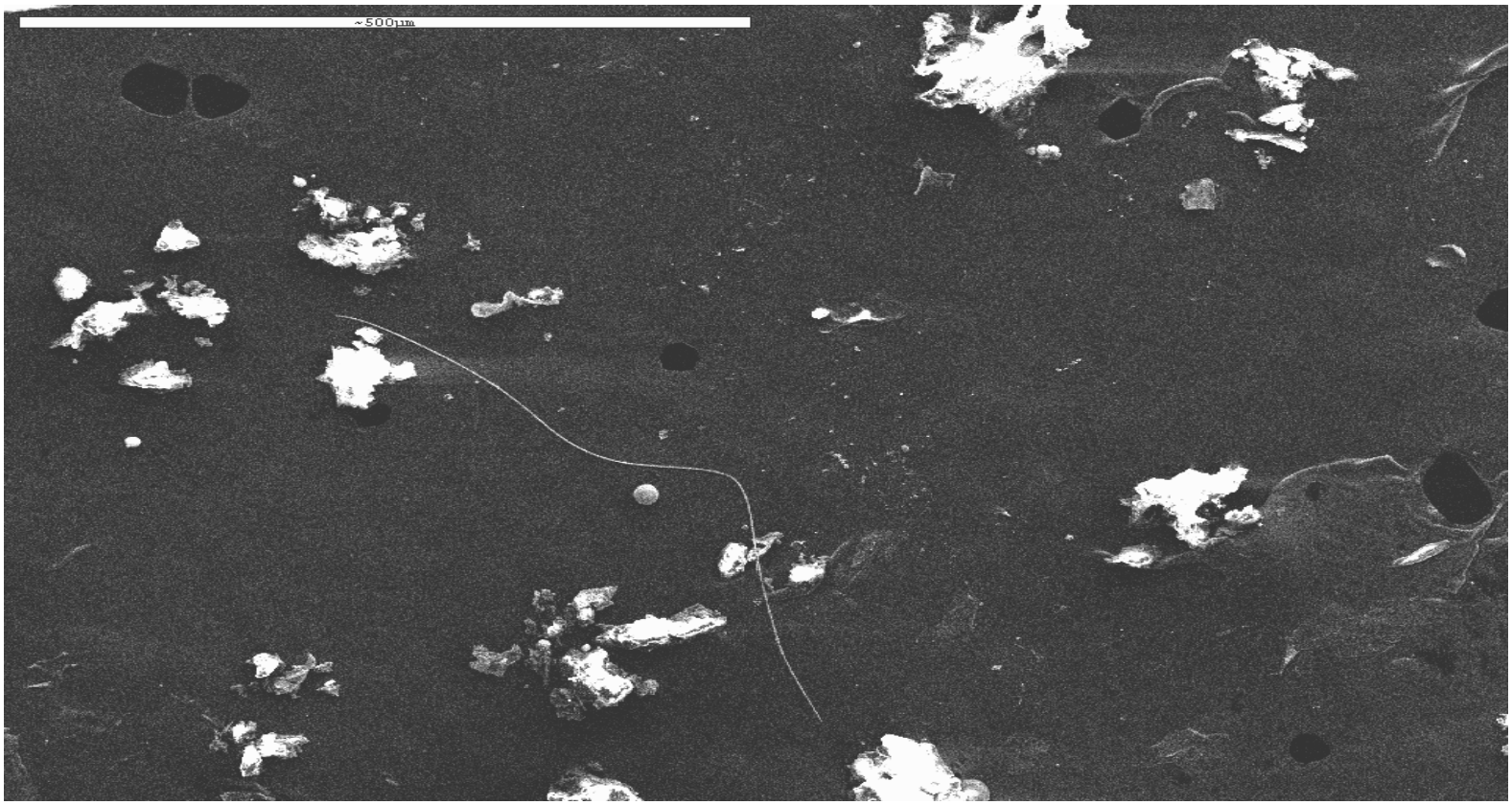
Screen Bypass Test
Iso-kinetic Downstream Sampling Ports



Screen Bypass Test



Screen Bypass Test SEM Photograph



Test Termination Criteria

- ***Measured HL increase <1% in 5 minutes***

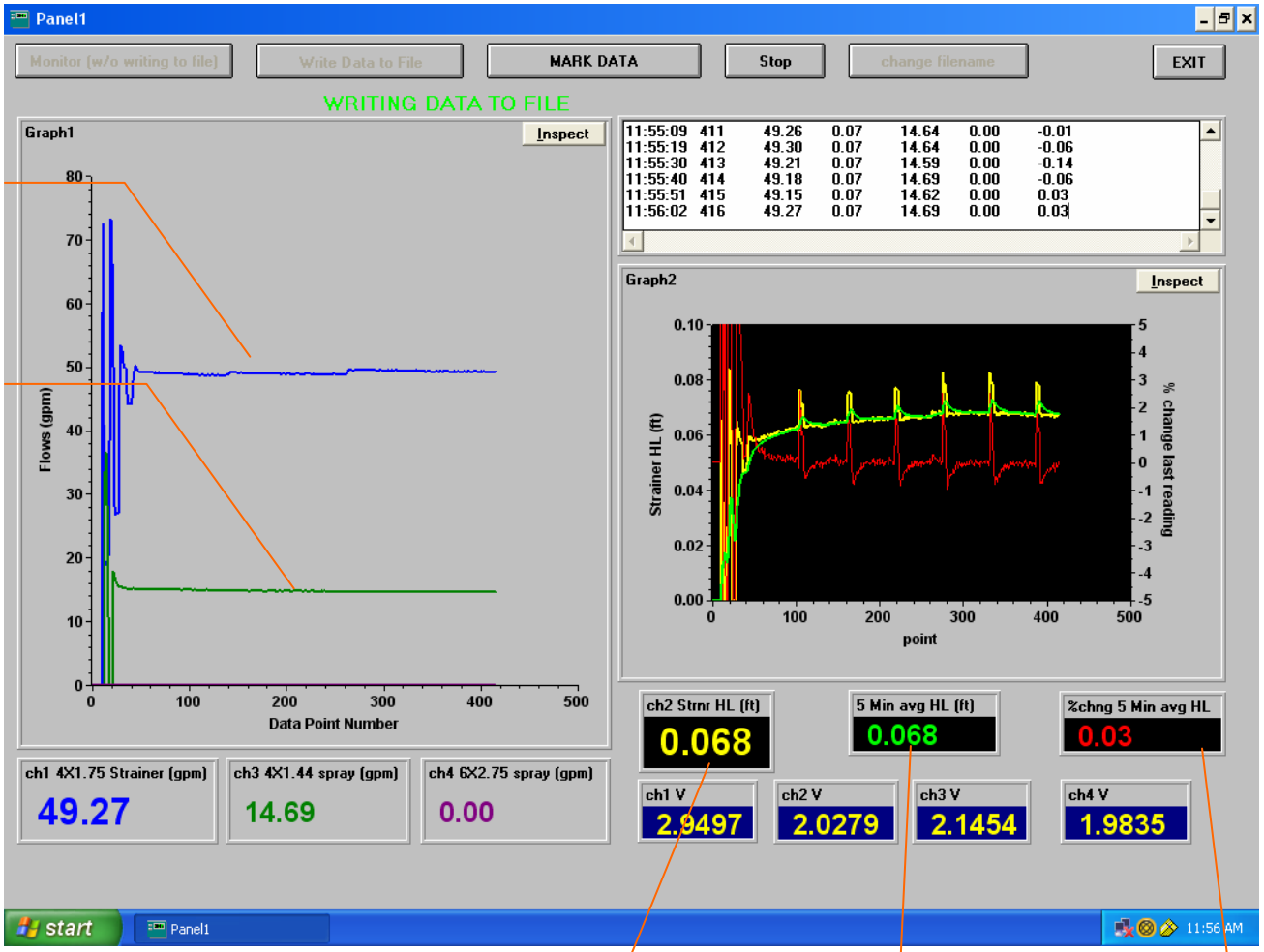
AND

- ***Calculated time for flume recirculation five times has been reached***
- ***Strainer tests durations have ranged from 1 hour to 6 hours***

Computer Screen

Flow (GPM) thru upstream piping

Flow (GPM) thru overhead piping



Head loss (ft)

5 minutes average HL

% change in 5 minutes average HL

Back Up Slides

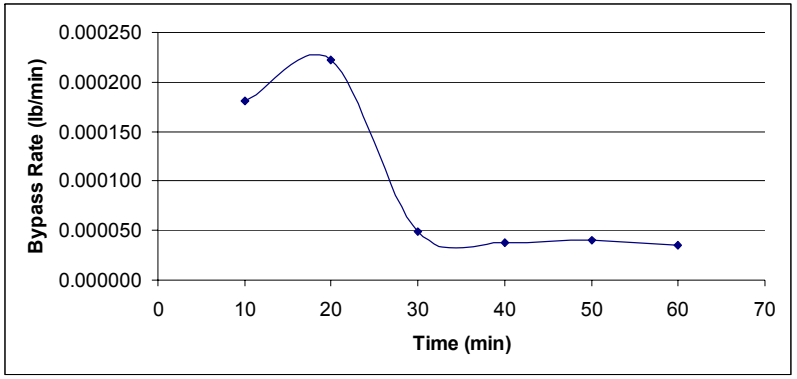
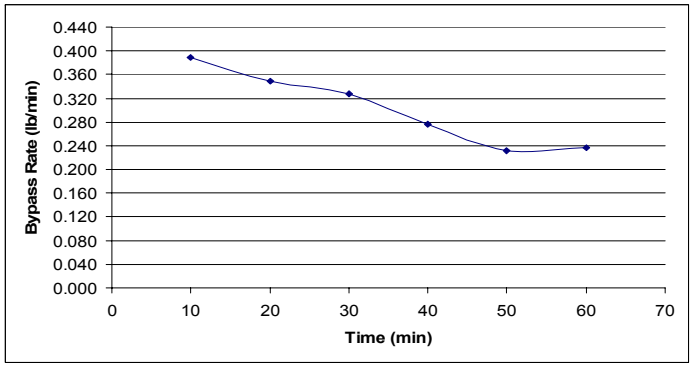
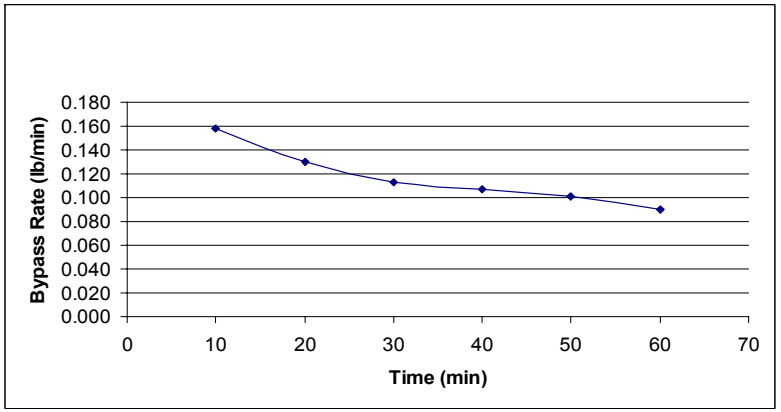
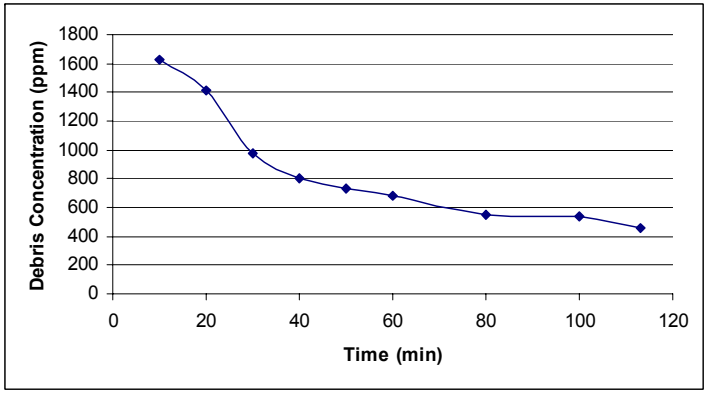
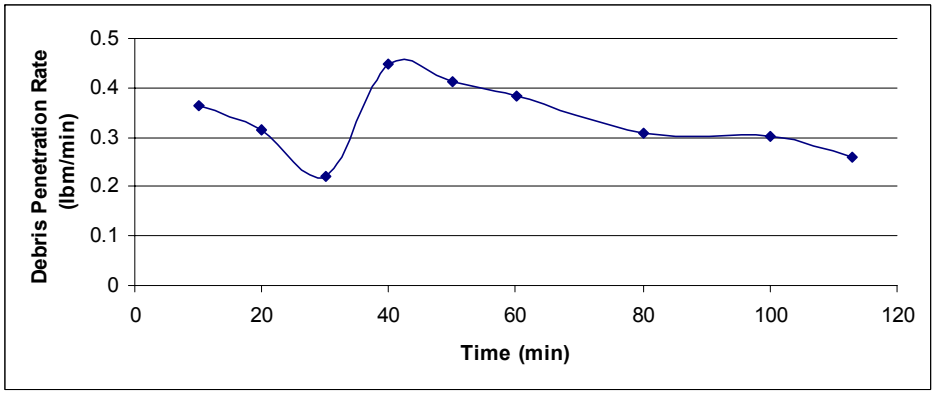
General Topics Item 2
Design Parameters Overview

Testing Recaps		1	2	3	4
Total Flow	gpm	5,200	2,200	19,100	18,750
Surface Area for Debris (Simple Screen)	ft^2	827.3	1,493.3	4,599.4	1,537.5
Reduction for Tags, Labels, Etc.	ft^2	0.0	0.0	0.0	0.0
Surface Area for Debris HL Calculations	ft^2	827.3	1,493.3	4,599.4	1,537.5
Approach Velocity @ Screen	ft / sec	0.0140	0.0033	0.0093	0.0272
Flow Rate Adjusted for Tags	gpm	5,200	2,200	19,100	18,750
Post LOCA Temperature for HL Calc	° F	65	212	120	133
Screen Submergence	in	2	3	~30	~67
Controlling NPSH Margin Available	ft	10.00	3.17	3.76	7.40
Testing Recaps		**5**	**6**	**7**	**8**
Total Flow	gpm	4,000	8,830	12,420	14,040
Surface Area for Debris (Simple Screen)	ft^2	768.7	3,279.5	3,992.8	3,595.6
Reduction for Tags, Labels, Etc.	ft^2	0.0	0.0	200.0	0.0
Surface Area for Debris HL Calculations	ft^2	768.7	3,279.5	3,792.8	3,595.6
Approach Velocity @ Screen	ft / sec	0.0116	0.0060	0.0073	0.0087
Flow Rate Adjusted for Tags	gpm	4,000	8,830	13,075	14,040
Post LOCA Temperature for HL Calc	° F	65	268	212	260
Screen Submergence for SFS 14	in	2	~13	10	3.36
Controlling NPSH Margin Available	ft	10.00	1.90	6.80	5.21

Specific Topics
Debris Testing - Scaling Methodology

- ***AREVA / PCI uses the size of the prototype strainer's surface area and the postulated strainer's surface area to scale all debris and flow for the debris tests.***
  - ***Prototype SFS 14 has 14.2 ft^2***
  - ***The postulated SFS arrangement has 3,595.6 ft^2***
  - ***Therefore, the scale used for the testing is expressed as:***
  - ***14.2 / 3595.6 = 0.0039493 or 0.39493% of the debris and flow rate***
  - ***See next slide for debris test allocation example***
- ***In our recent high fiber tests, we further adjusted the prototype test flow rate higher to also test at the postulated circumscribed flow rate of the postulated strainer system.***
  - ***SFS 14 flow rate increased from 55.5 gpm to 110.8 gpm for the high fiber test***

Specific Topics
Debris Testing – Scaling Methodology

Test No. 1			LBLOCA Design Condition - Max Fiber Content				Data Not Finalized
Debris Type	U/M	Quantity	Wt Conversions (lbs / ft³ or ft²)	Debris Scaled to Test Module	Debris Qty + 0%	U/M	Debris Form / (Surrogate)
RMI	ft²	13,694	n/a	4.40	4.40	lbm	2 mil thick SS foil
1/2" x 1/2" pieces (24.5%)	ft²	3,355	0.0813	1.078	1.08	lbm	2 mil thick SS foil
1" x 1" pieces (20.9%)	ft²	2,862	0.0813	0.920	0.92	lbm	2 mil thick SS foil
2" x 2" pieces (54.6%)	ft²	7,477	0.0813	2.403	2.40	lbm	2 mil thick SS foil
Coatings (lbs)							
IOZ (Qualified 10D)	lbm	2,615	n/a	10.335	10.34	lbm	Powder (Tin @ 455 lb/ft³)
IOZ (Unqualified)	lbm	884	n/a	3.494	3.49	lbm	Powder (Tin @ 455 lb/ft³)
Sub-Total Primers				**13.83**	**13.83**	lbm	Powder (Tin @ 455 lb/ft³)
Epoxy (10D Qualified)	lbm	2,938	n/a	11.611	11.61		
Polyamide Primer (10D Qualified)	lbm	21	n/a	0.083	0.08	lbm	Powder (Walnut Shell Flour; 75 to 93.6 lb/ft³)
Epoxy (Unqualified)	lbm	1,815	n/a	7.173	7.17	lbm	Powder (Walnut Shell Flour; 75 to 93.6 lb/ft³)
Alkyds (Unqualified)	lbm	310	n/a	1.225	1.23	lbm	Powder (Walnut Shell Flour; 75 to 93.6 lb/ft³)
Baked Enamel (Unqualified)	lbm	269	n/a	1.063	1.06	lbm	Powder (Walnut Shell Flour; 75 to 93.6 lb/ft³)
Sub-Total Coatings				**21.16**	**21.16**	lbm	Powder (Walnut Shell Flour; 75 to 93.6 lb/ft³)
Fibers							
Latent Fiber	ft³	12.5	2.4	0.119	0.12	lbm	Finely Shredded (NUKON)
NUKON	ft³	591.1	2.4	5.607	5.607	lbm	Shredded
Thermal Wrap	ft³	840.0	2.4	7.967	7.967	lbm	Shredded (Knauf ET or NUKON)
Microtherm	ft³	1.8	15.0	0.107	0.107	lbm	Shredded
Marinite	ft³	15.1	14.5	0.865	0.865	lbm	Shredded
Particulates							
Latent Particulate; Dirt & dust	lbm	170	n/a	0.672	0.67	lbm	(PCI PWR Mix)
Tags & labels (sq ft)							
Labels, Tape & Misc Debris	ft²	100	1.000	0.395	0.40	ft²	Provided by Client (Use ~0.6 ft² test)
Chemical Debris Precipitant Concentrations							
Sodium Aluminum Silicate ($NaALSi_3O_8$)	lbm	1,619	n/a	6.398	6.40	lbm	Powder
Calcium Phosphate - $Ca_3(PO_4)_2$	lbm	396	n/a	1.565	1.57	lbm	Powder
Aluminum Oxyhydroxide (ALOOH)	lbm	141	n/a	0.557	0.56	lbm	Powder (Aluminum Hydroxide)
Other Conditions		Proposed	Test Module SFS 14				
Total flow (2 of 3 Sumps)	gpm	14,040	55.5			0.0%	Bump Up Factor for the Prototype Flow
Surface Area for Debris (2 of 3 Sumps)	ft²	3,595.6	14.2	See PCI TDI-6005-01 Rev 0; Surface Area & Flow Calc LBLOCA			
Reduction for Tags, Labels, Etc.	ft²	0.0	0.0				
Surface Area for Debris HL Calculations	ft²	3,595.6	14.2				
Approach Velocity @ Screen	ft / sec	0.0087	0.0087				
Flow Rate Adjusted for Tags	**gpm**	14,040	**55.5**				
Flow Required to Match Circumscribed Area	**gpm**	n/a	**110.8**				
Fiber Qty Estimated for Peak HL	ft³	n/a	n/a				
Post LOCA Temperature for HL Calc		260 ° F					
Screen Submergence for SFS 14	in	3.36	Based on LBLOCA Minimum Water 3.03'; EL -8' - 2-5/8"				
Controlling NPSH Margin Available	ft	5.21	CS limits head loss; 21.61' $_{Avail}$ - 16.4' $_{Req'd}$				

Samples of Debris Bypass Rates