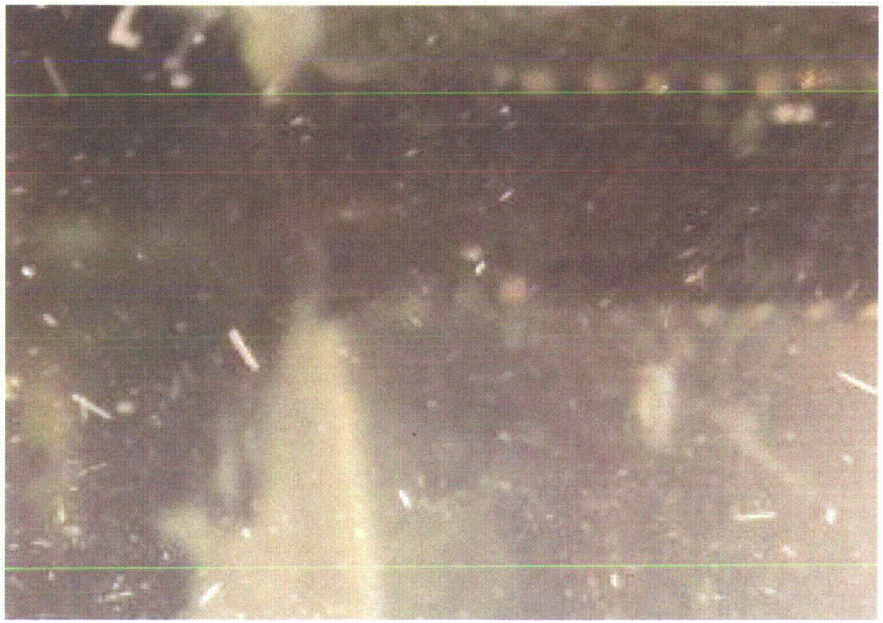
GSI-191

Fibrous Debris Characterization Bench-Top Test Program

Overview

- Bench-Top Test Objective
- Methodology
- Fiber Preparation
- Parameters Tested
- Bench-Top Testing
- Report



Bypassed Fiber

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Bench-Top Test Objective

- Establish a fiber length distribution(s) to represent the prototypical fiber that may bypass containment ECCS strainers.
  - Inputs to testing based on PWROG survey results
  - Objective not to determine fiber bypass quantity
  - The tests are not "pass / fail" but provide representative fiber length distribution(s) for use in future testing related to fuels
  - Does not require that every plant specific parameter is tested (not plant specific testing)

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Methodology

- Design of Experiment approach
  - Test several variables with minimal test to determine factors important to fiber length
- Fiber-only bypass tests on a bench-top test loop
- Isokinetic debris sampling
- Microscopic analysis of bypassed fiber to determine the length distribution
- Statistical analysis of the microscopic fiber lengths

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Fiber Preparation

- NEI Debris Preparation: "ZOI Fibrous Debris Preparation: Processing, Storage, and Handling"
- Water chemistry used during test was used to prepare debris
  - Pressure washer connected to buffered / borated water storage tank for chemically treated water
- Typically 1.5 to 2.2 grams per gallon dilution (per batch of debris)
  - (0.0033 to 0.0047 pounds per gallon)

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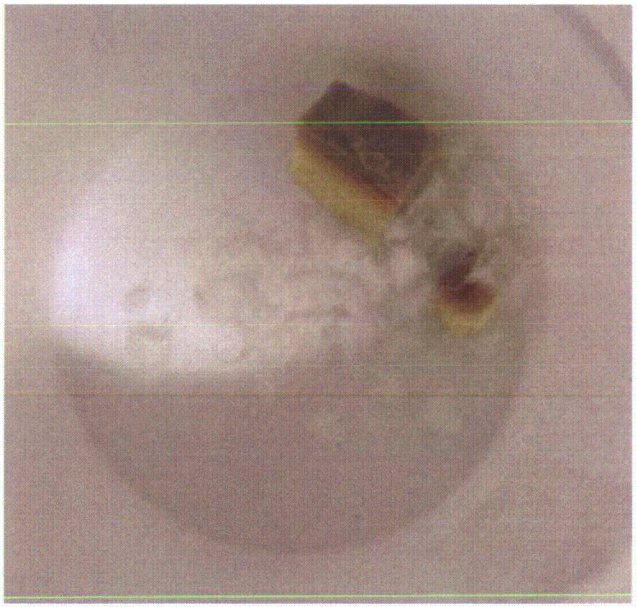
Fiber Preparation

1/16th inch batch preparation



Nukon and Temp-Mat

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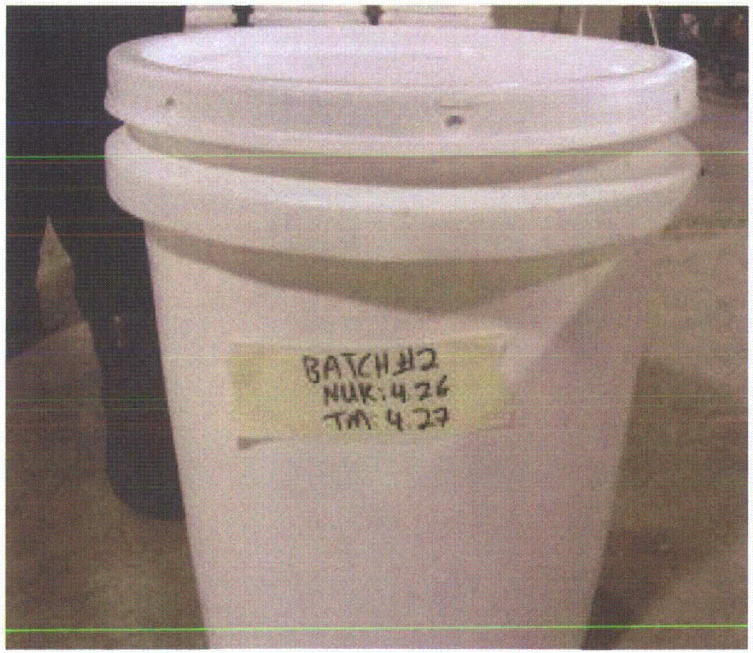
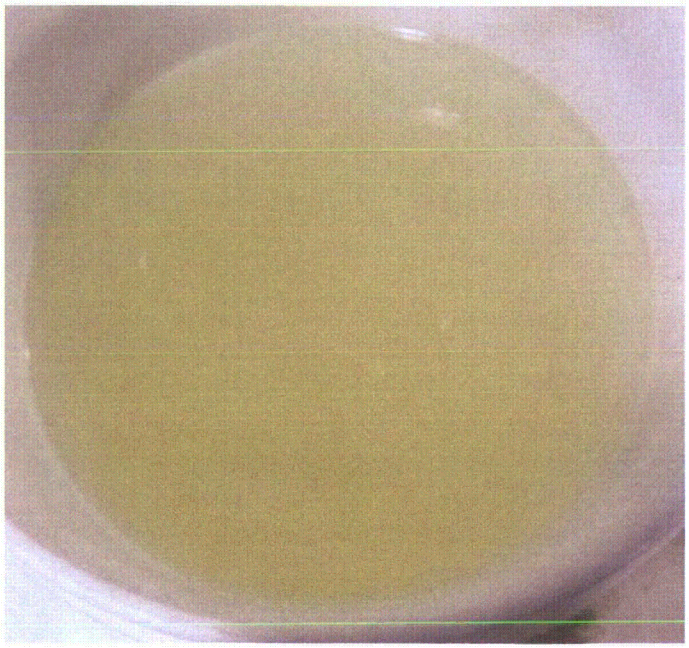
Fiber Preparation





1/16th inch batch preparation

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Parameters Tested

- Water Chemistry
- Fiber Type
- Hole Size
- Approach Velocity
- Percent Open Area
- Strainer Shape (angle of attack)
- Temperature
- Agitation

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Parameters Tested

- Water Chemistry
  - Tap
  - 2000 ppm Boron buffered with NaOH
  - 2000 ppm Boron buffered with TSP
  - 500 ppm Boron buffered with NaOH (not used)
  - 500 ppm Boron buffered with TSP (not used)
- Fixed strainer shape, hole size, velocity, percent open area, & fiber type for the water chemistry tests to eliminate the parameter

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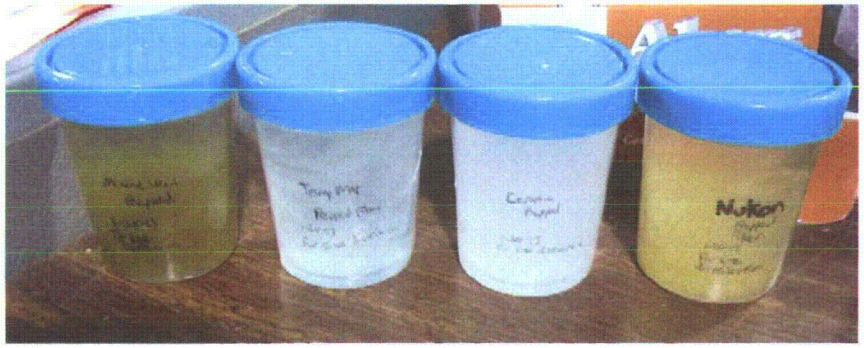
Parameters Tested

- Fiber Type
  - Initially analyzed Nukon, Ceramic fiber, Temp-Mat, & Mineral Wool after NEI prep
  - Based on industry survey response
  - Nukon, Ceramic fiber and mineral wool are very similar
  - Tested with Nukon and Temp-Mat (long fibers)



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Parameters Tested

- Hole Size
  - Based on industry survey
    - 0.0459", 0.063", 0.094", 0.125" & 0.1875"
    - 13 test-section strainers constructed
  - Most test focused on 0.063", 0.094" & 0.125"
    - Represented vast majority of plants
  - 0.0459" & 0.1875" tested at the end of test program to cover the extremes

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Parameters Tested

- Approach Velocity
  - Based on industry survey
  - Covered representative approach velocities to analyze representative fiber distributions
  - Most tests utilized 0.007 ft/sec or 0.02 ft/sec
  - Middle values also used in some tests
  - 0.002 ft/sec and 0.045 ft/sec tested at the end of test program to cover the extremes
  - Flows varied based on the strainer surface areas

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Parameters Tested

- Percent Open Area
  - Tested between 23% and 40% open area
  - Based on industry survey

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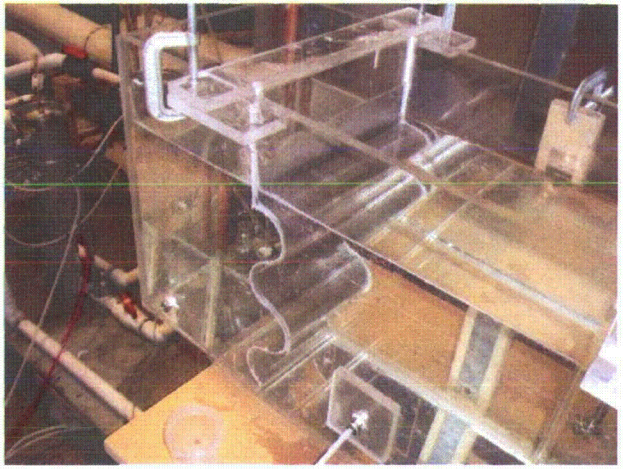
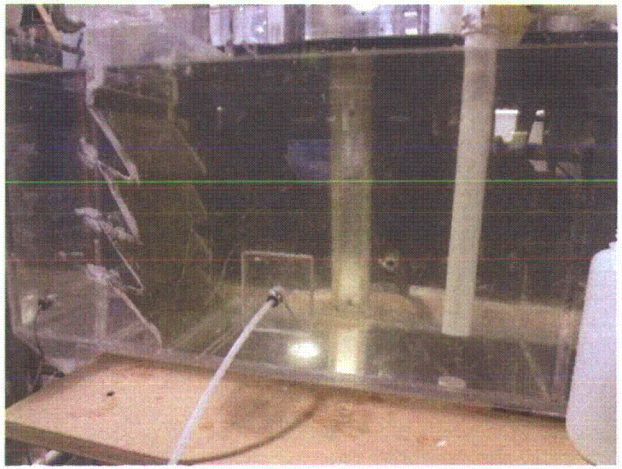
Parameters Tested

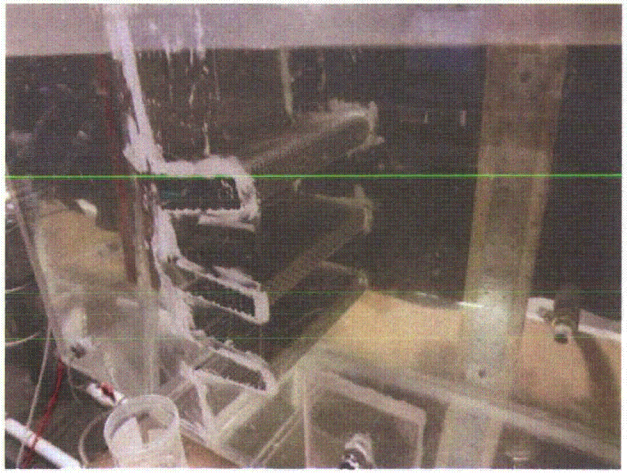
- Strainer Shape – 13 strainers



Curved



Corrugated



Finned

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Parameters Tested

- Temperature
  - 80°F, 100°F, 120°F
- Determine importance of viscosity effects on bypass testing

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Parameters Tested

- Agitation
  - Varied agitation
  - Small portion of flow recirculated using peristaltic pump (not the recirculation pump) that took suction upstream of the strainer and reintroduced flow upstream of the strainer (pictures to follow)
  - Varied nozzle fitting size to vary agitation

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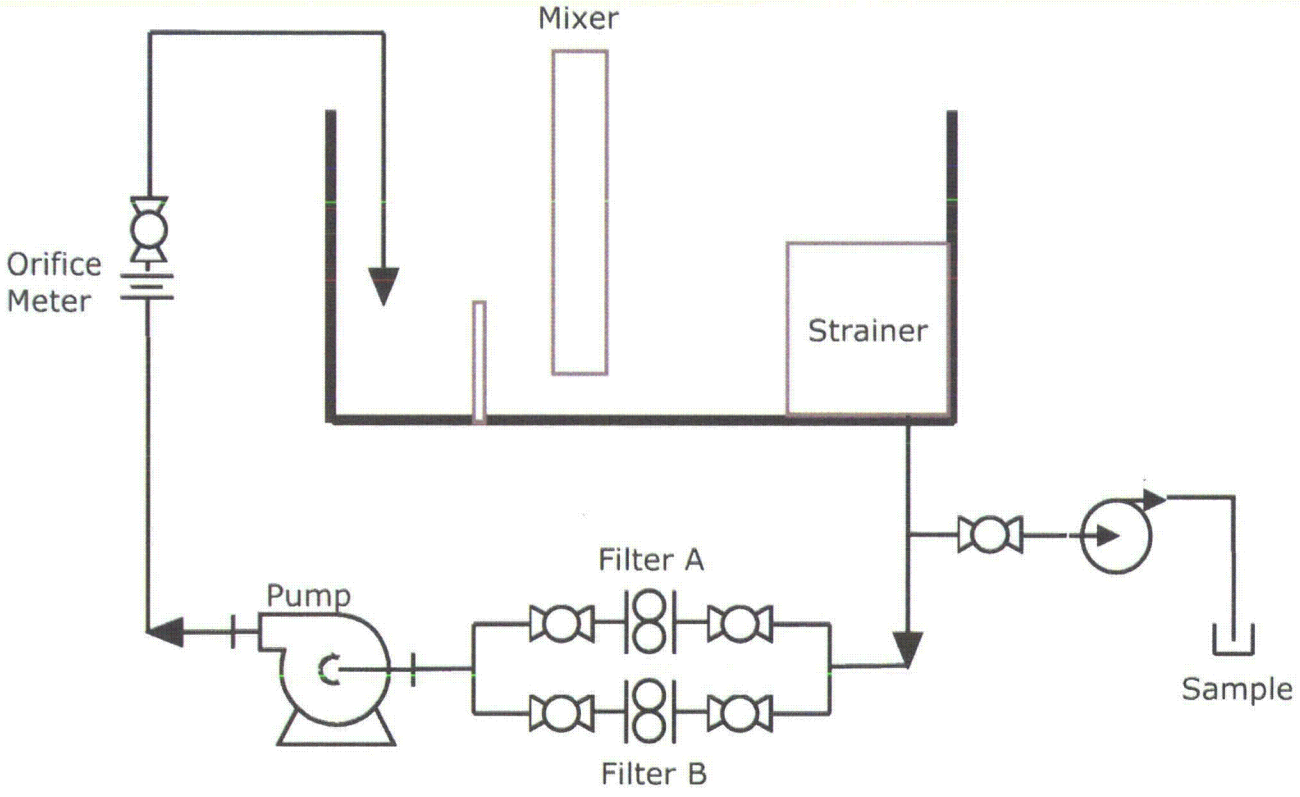
Bench-Top Testing



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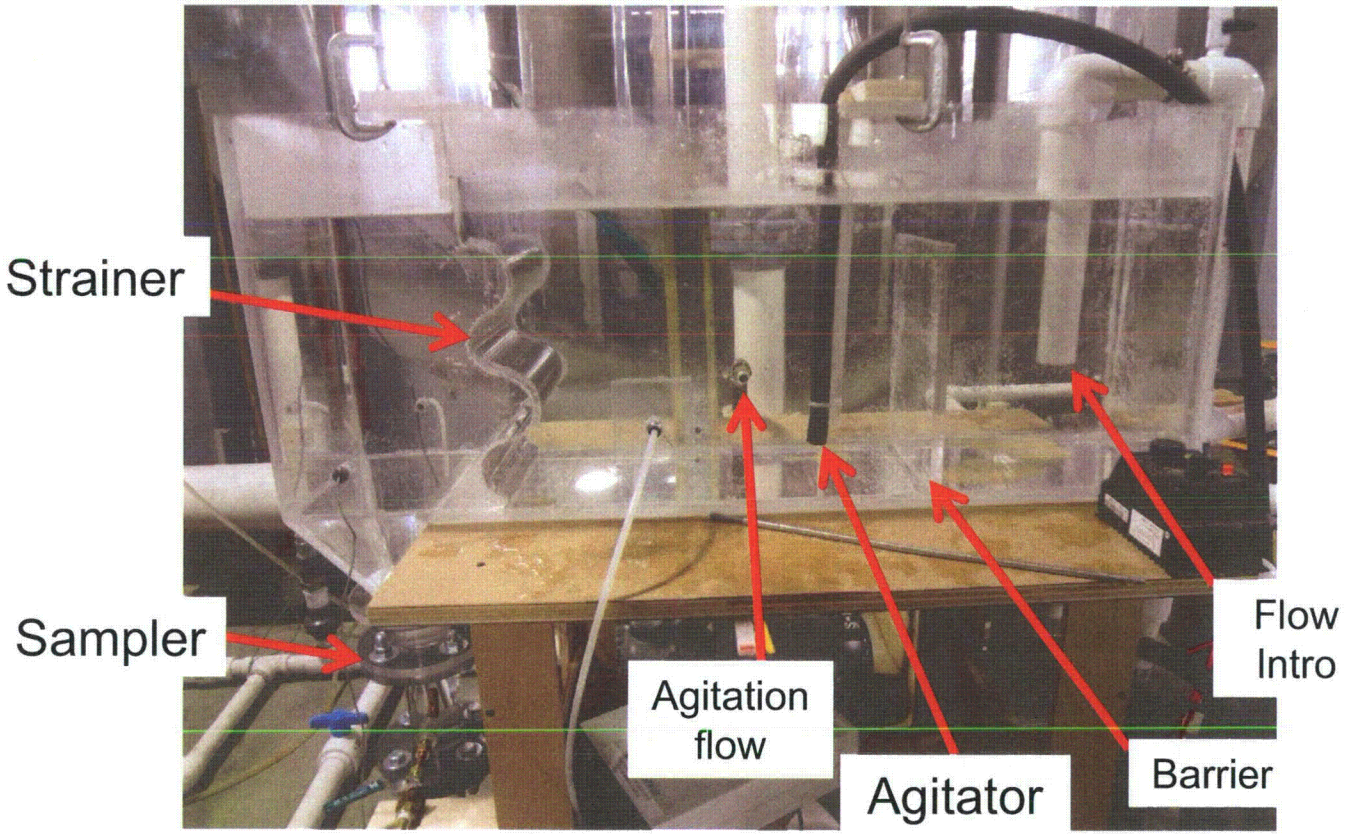
Bench-Top Testing



Test Tank: ≈10”W x 12”D x 36”L

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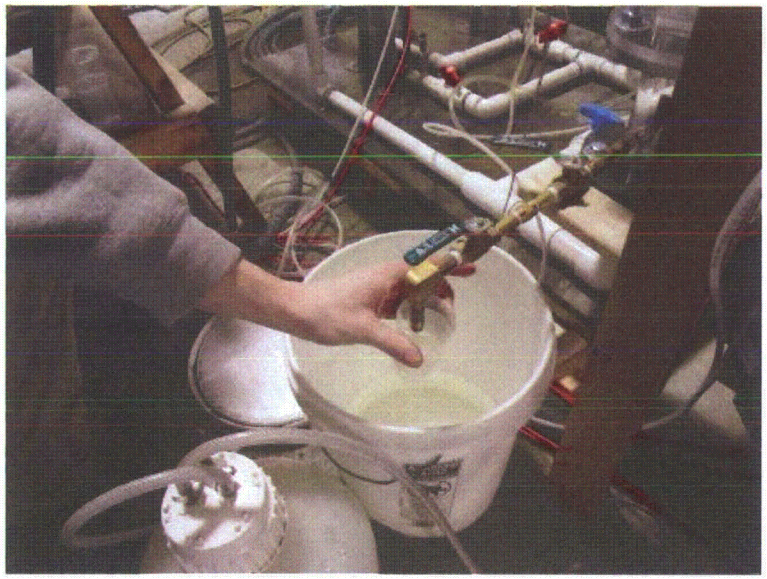
Bench-Top Testing



Sample Station

Bench-Top Testing

- Debris addition sequence table
- All fiber tested assumed a LDFG fabricated density of 2.4 lbm/ft^3

Batch #	Fiber Addition (bed thickness in inches)	Total Bed Thickness (inches)
1	1/16	1/16
2	1/16	2/16
3	1/16	3/16
4	1/16	2/8
5	1/8	3/8
6	1/8	1/2

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Bench-Top Testing

- Introduced debris
  - Took approximately 3 minutes
- Sample after one turnover
  - 3 minute turnover for lower-velocity tests
  - 1 minutes turnover for higher-velocity tests
- Second sample after three turnovers
- Fiber Bed covered strainer by completion of second fiber introduction

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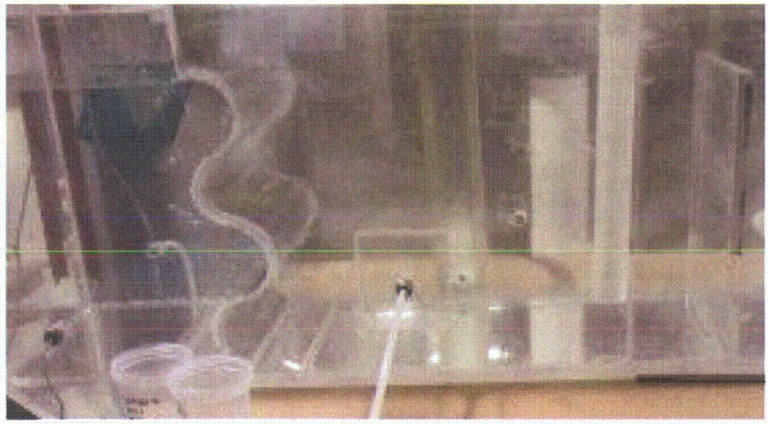
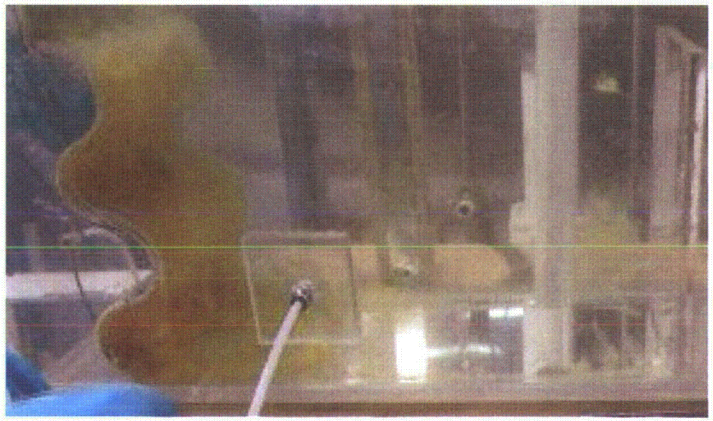
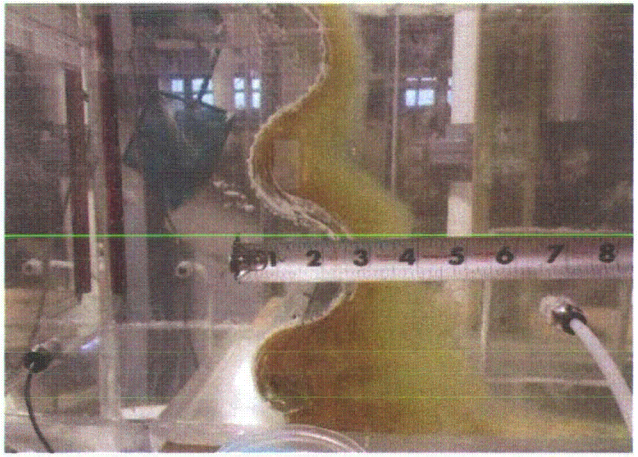
Bench-Top Testing



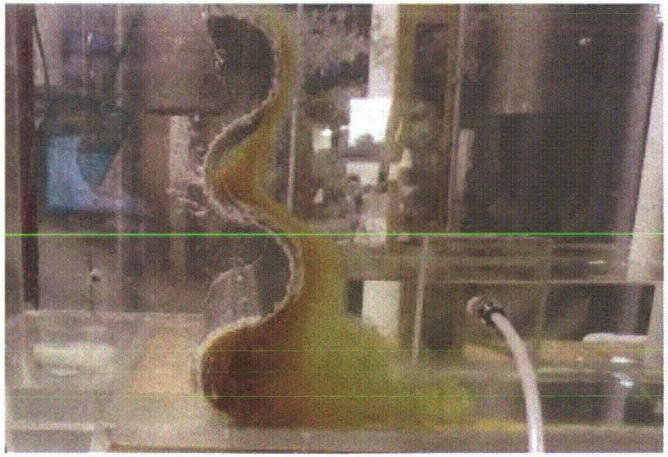
After initial fiber add



After 1/8th inch bed add



After 1/2th inch bed add



Drain down

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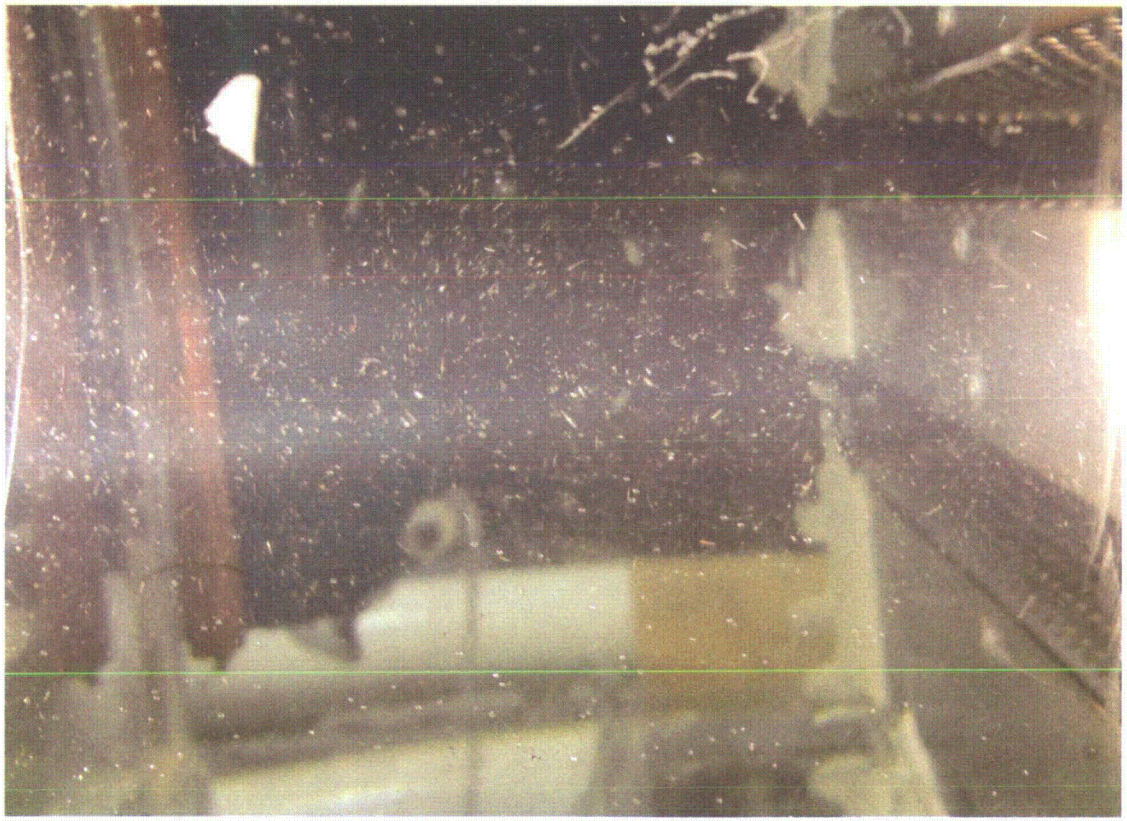
Bench-Top Testing



Flashlight-aided downstream picture

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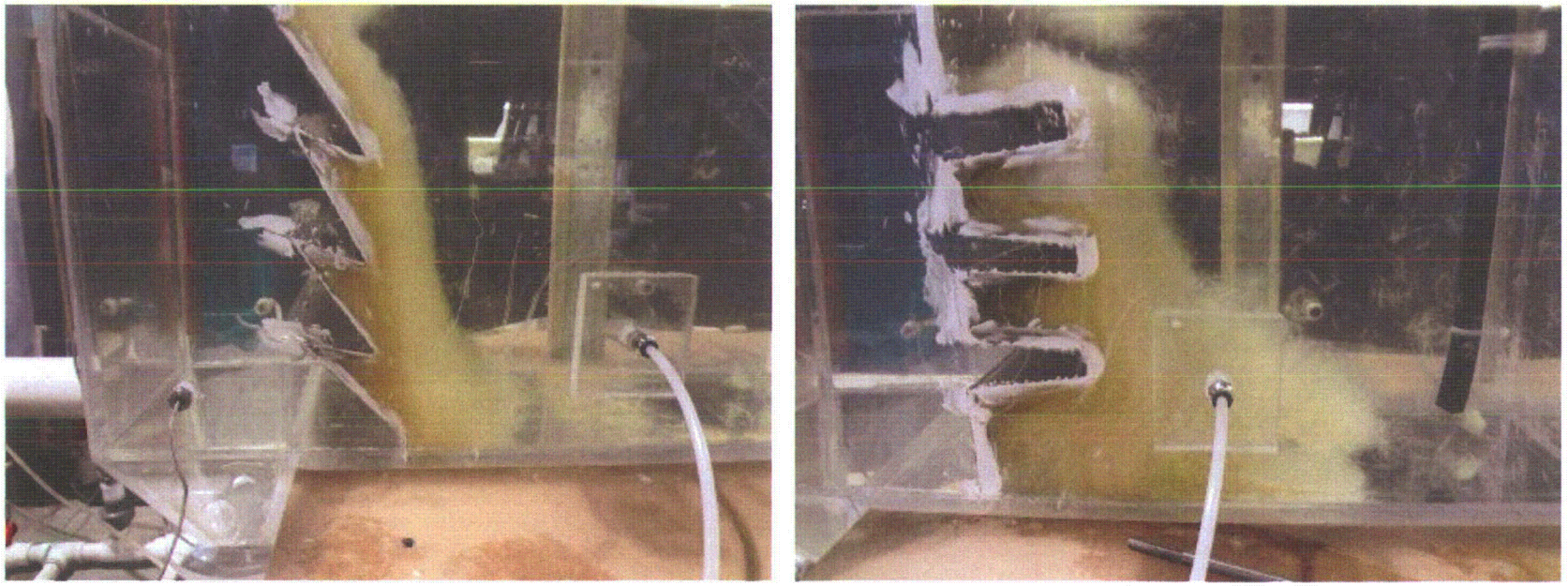
Bench-Top Testing



Two tests after all debris addition

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Bench-Top Testing

- 31 tests completed between January 28th and March 13th
- Analysis performed in conjunction with tests to complete DOE methodology
- Test utilized mostly the first sample
  - Some analysis performed on second sample to look at variability
- Approximately 300 fiber lengths documented per sample

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Bench-Top Testing

Test Number	Flow Rate (gpm)	Turnover Time (min)	Temperature (deg F)	Strainer Hole Size (in)	Open Area (%)	Strainer Shape	Fiber Type	Target Velocity (ft/s)	Boron Concentration	Agitation Setting	Water Chemistry
1B	6.31	3.07	80	0.094	33	Curved	NUKON	0.0135	N/A	High	Tap
2	6.31	3.07	120	0.094	33	Curved	NUKON	0.0135	N/A	Low	Tap
3	6.31	3.07	120	0.094	33	Curved	NUKON	0.0135	N/A	Low	Tap
4	6.31	3.07	80	0.094	33	Curved	NUKON	0.0135	2000 ppm	Low	Borated / NaOH
5	6.31	3.07	120	0.094	33	Curved	NUKON	0.0135	2000 ppm	High	Borated / NaOH
6	6.31	3.07	80	0.094	33	Curved	NUKON	0.0135	2000 ppm	Low	Borated & TSP
7	4.53	4.33	120	0.125	40	Finned (Disk)	NUKON/TM/MW	0.0070	N/A	High	Tap
8	12.94	1.50	80	0.125	40	Finned (Disk)	50% NUKON/TM	0.0200	N/A	Low	Tap
9	12.86	1.50	80	0.063	23	Finned (Disk)	81% NUKON/TM	0.0200	N/A	High	Tap
10	4.50	4.30	120	0.063	23	Finned (Disk)	50% NUKON/TM	0.0070	N/A	Low	Tap
11	13.20	1.47	120	0.063	40	Corrugated	81% NUKON/TM	0.0200	N/A	Low	Tap
12	4.60	4.20	80	0.063	40	Corrugated	50% NUKON/TM	0.0070	N/A	High	Tap
13	4.70	4.12	80	0.125	23	Corrugated	81% NUKON/TM	0.0070	N/A	Low	Tap
14	13.44	1.44	120	0.125	23	Corrugated	50% NUKON/TM	0.0200	N/A	High	Tap
15	13.52	1.43	80	0.125	40	Corrugated	81% NUKON/TM	0.0200	N/A	High	Tap
16	4.73	4.10	120	0.125	40	Corrugated	50% NUKON/TM	0.0070	N/A	Low	Tap
17	4.51	4.33	80	0.063	40	Finned (Disk)	81% NUKON/TM	0.0070	N/A	Low	Tap
18	12.90	1.50	120	0.063	40	Finned (Disk)	50% NUKON/TM	0.0200	N/A	High	Tap
19	4.72	4.17	120	0.063	23	Corrugated	81% NUKON/TM	0.0070	N/A	High	Tap
20	13.48	1.50	80	0.063	23	Corrugated	50% NUKON/TM	0.0200	N/A	Low	Tap
21	12.94	1.50	120	0.125	23	Finned (Disk)	81% NUKON/TM	0.0200	N/A	Low	Tap
22	4.53	4.33	80	0.125	23	Finned (Disk)	50% NUKON/TM	0.0070	N/A	High	Tap
23	9.12	2.13	100	0.094	33	Corrugated	66% NUKON/TM	0.0135	N/A	Medium	Tap
24	6.31	3.07	100	0.094	33	Cylinder	66% NUKON/TM	0.0135	N/A	Medium	Tap
25	8.52	2.28	100	0.094	33	Finned (Disk)	66% NUKON/TM	0.0135	N/A	Medium	Tap
26	13.44	1.50	100	0.1875	33	Corrugated	NUKON	0.0200	N/A	Medium	Tap
27	19.64	1.00	100	0.094	33	Cylinder	NUKON	0.0450	N/A	Medium	Tap
28	4.47	4.33	100	0.045	28	Finned (Disk)	81% NUKON/TM	0.0070	N/A	Medium	Tap
29	12.78	1.50	100	0.0459	28	Finned (Disk)	NUKON	0.0200	N/A	Medium	Tap
30	18.68	1.00	100	0.094	33	Finned (Disk)	NUKON	0.0296	N/A	Medium	Tap
31	1.26	15.50	100	0.094	33	Finned (Disk)	NUKON	0.0020	N/A	Medium	Tap

Matrix of Tests Performed (DOE Methodology)

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Report

- Microscopic analysis of fiber
  - Length compared to NIST traceable calibration SEM artifact
- Statistical analysis determined parameter importance to fiber length distribution
- Compiling data – Prelim results suggest that:
  - Velocity and hole size are the predominant factors in length distribution

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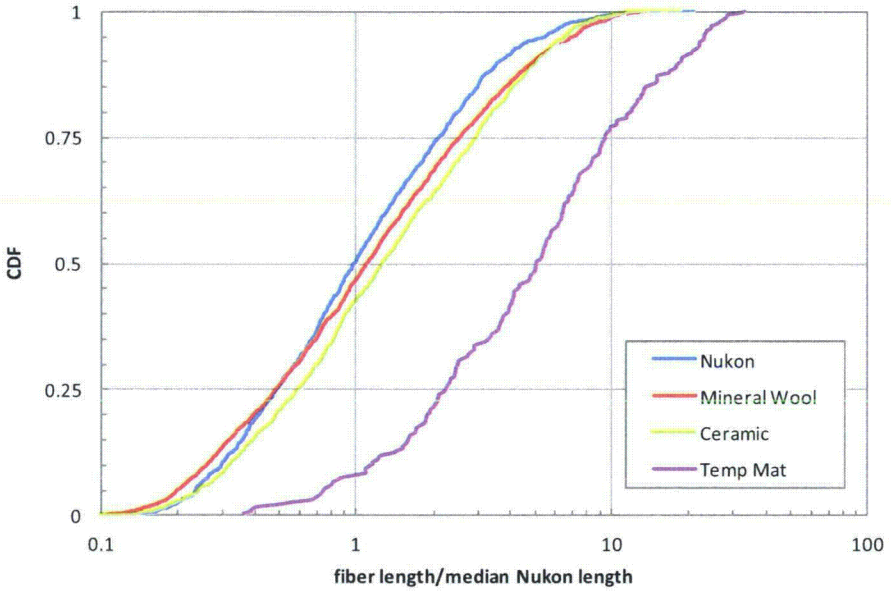

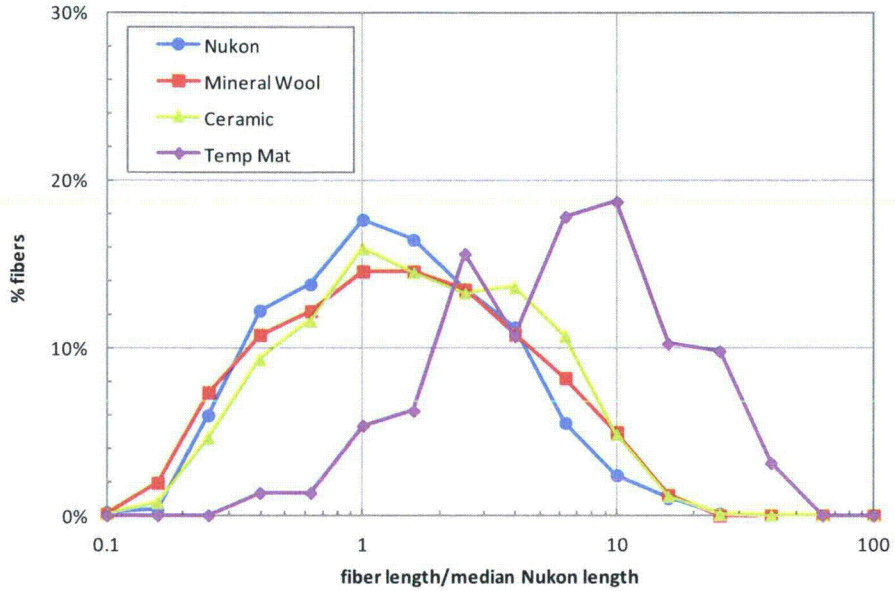

- Cumulative distribution function (left) and histogram (right) of NEI-prepared fiber
- Lengths shown on a logarithmic scale, relative to the median length measured for Nukon
- Prepared Nukon, mineral wool, and ceramic have very similar distributions
- Temp-Mat is significantly longer: median Temp-Mat fiber is more than 5x longer than median Nukon fiber

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Questions?