Appendix D – Large-Scale Data Acquisition System Worksheets

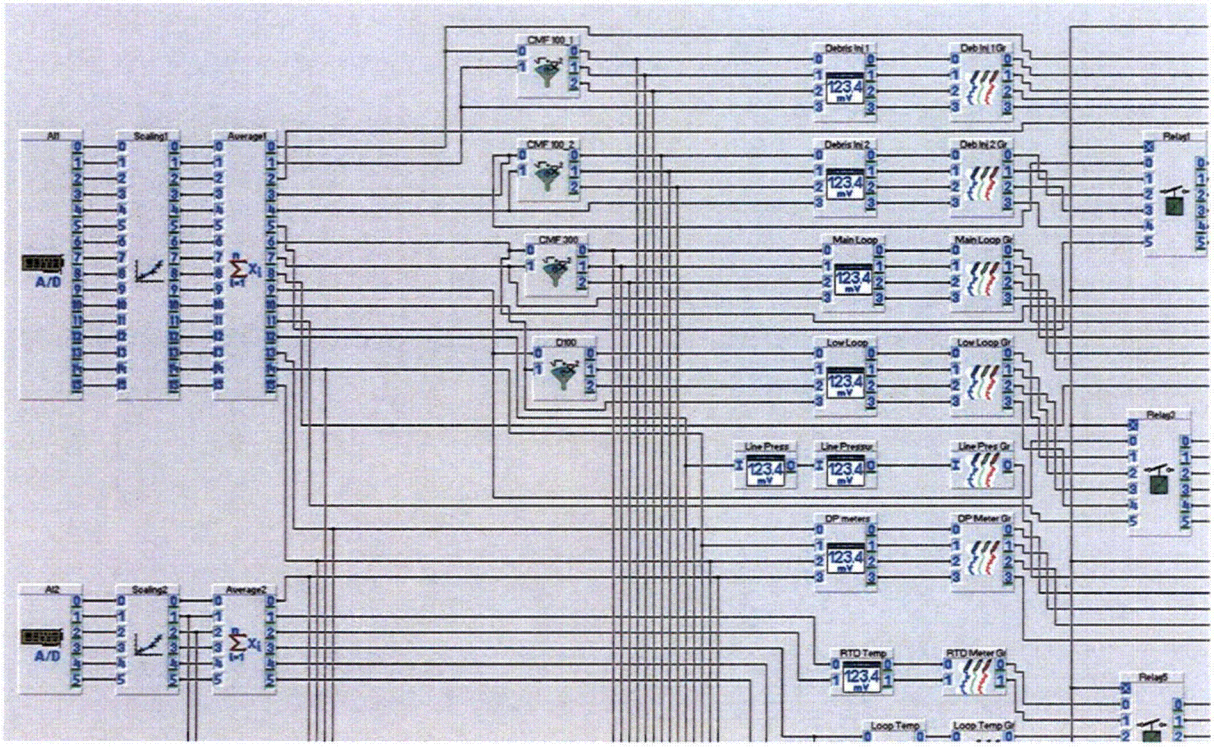


Figure D.1.1. Large-Scale DAS Worksheet, Top-Left Corner

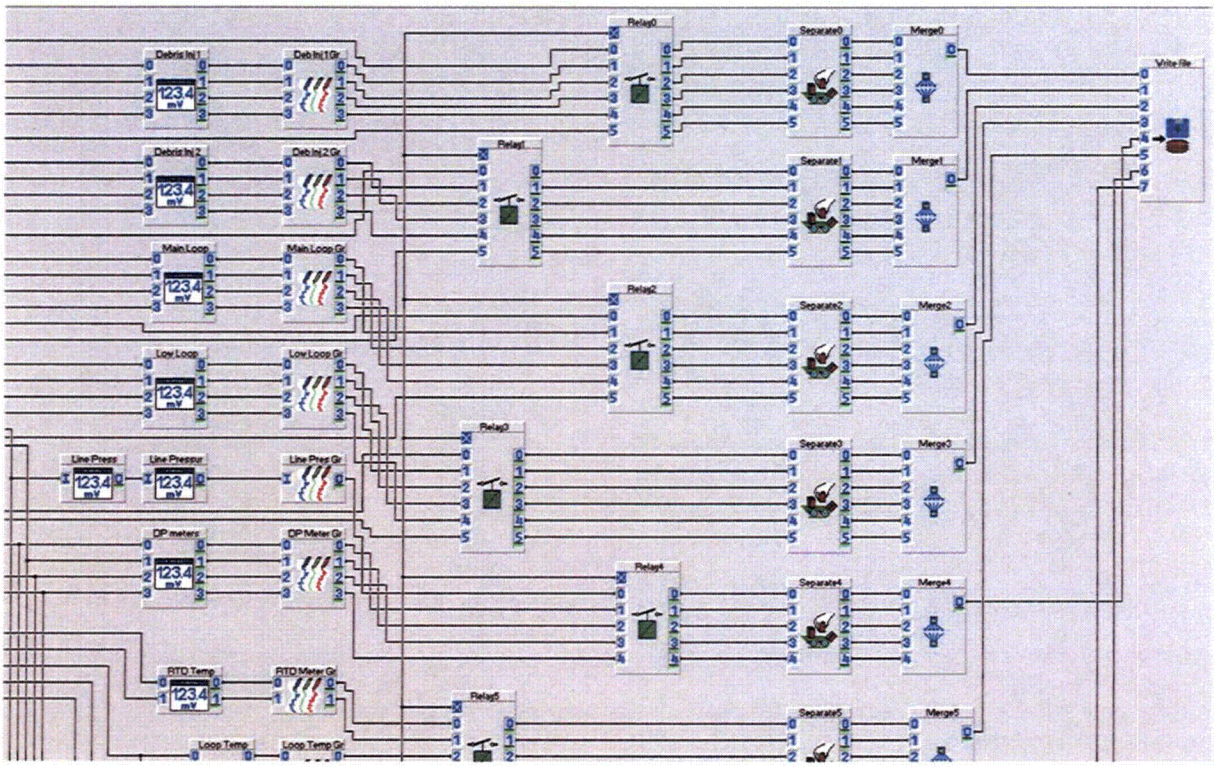


Figure D.1.2. Large-Scale DAS Worksheet, Top-Right Corner

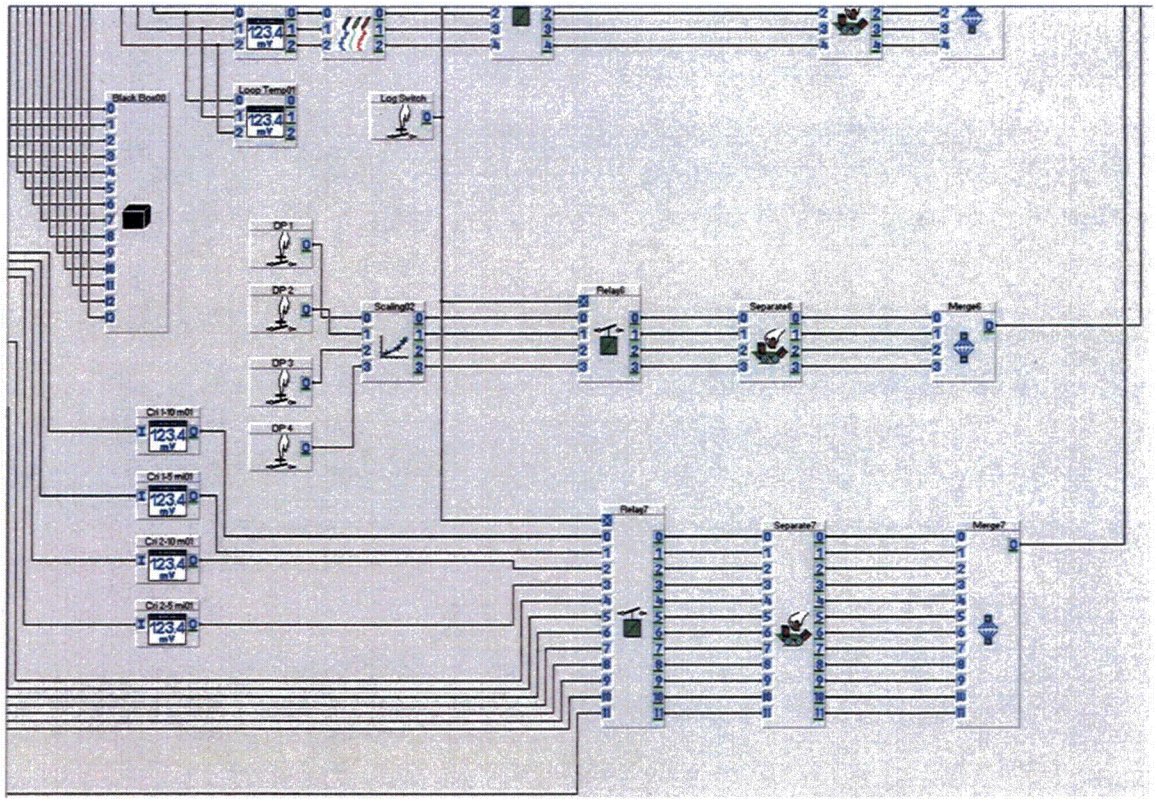


Figure D.1.3. Large-Scale DAS Worksheet, Lower Right Corner

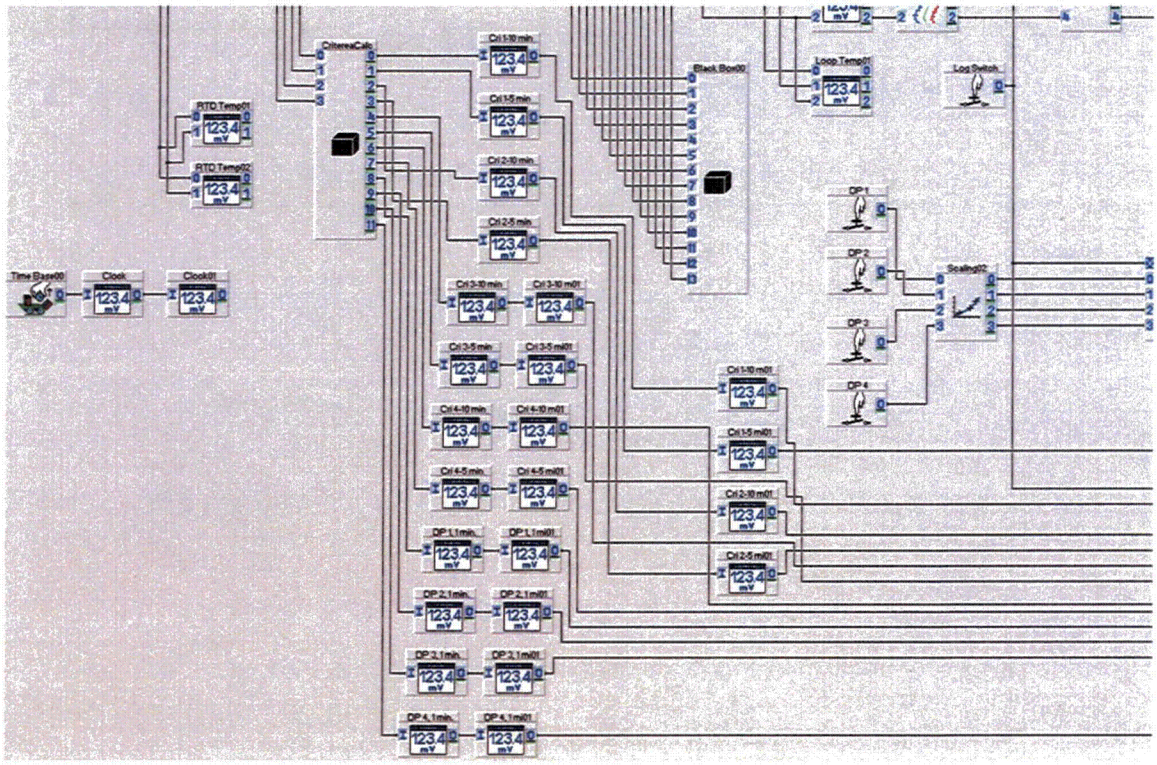


Figure D.1.4. Large-Scale DAS Worksheet, Lower Left Corner

Appendix E

Debris Preparation Procedures

Appendix E – NUKON Debris Preparation R4 Metric Procedure

This procedure defines the process used by PNNL to quantify NUKON preparation.

1. Dry a quantity of received NUKON in an oven at nominally 90°C until a steady mass (within the uncertainty of the scale) is reached.
2. Select the required mass for testing from the dried material of Step 1.
3. Based on a dilution ratio of 12.5 g of NUKON to 500 mL of water obtained from personnel communication with previous investigators (Shaffer et al. 2005), the blender volume limits, and with consideration of the indicated applicability range of the R4 metric (see Section 3.2.1.1 of *Debris Preparation Determination* draft write-up), determine the mass of NUKON to be prepared and its associated water volume. Multiple sub-batch preparations may be required to reach a total batch target debris loading.
4. The R4 metric is determined from

$$R4 = \frac{\text{Nukon and Water Mass on Screen}}{\text{Initial Nukon Mass}} \tag{1}$$

   and the R4 test is conducted by

   a. Place NUKON mass and water volume (from Step 3) into blender.
   b. Prepare the material at a specific blender setting for a specified time. R4 results depend on blender type, operation, and preparation time. Refer to Section 3.2.1.2
   c. Upon completion of the preparation, immediately pour the NUKON and water through an 8 in diameter 5-mesh screen into a container. When pouring the slurry through the 5-mesh screen, exercise care to ensure that the material is poured through an "unused" portion of the screen (i.e., do not pour onto retained NUKON and water). After the bulk of the slurry is poured out, add sufficient water to the blender (on the order of 100 mL) to flush all of the debris material out and through the screen.
   d. Remove excess water from the screen prior to the mass measurement by tapping the screen five times on the rim of the collection container, rotating it 90° CCW, and then tapping five more times. The tapping is conducted by grasping the screen on either side and raising it approximately 1 in vertically above the rim of the container and then lowering it to tap it on the rim. The force of the tap is generated by the mass of the screen, NUKON debris, and water.
   e. Immediately weigh the NUKON and water mass on the screen (total mass minus dry screen tare).

NUKON Debris Preparation Procedure

Equipment:

Scale: Sartorius BP 3100 S or scale with similar accuracy.

Container to measure water volume with a scale sufficient to be able to differentiate ± 25 mL.

Blender used: _____. Use the provided lid that came with the blender.

Stop watch with the ability to differentiate seconds.

NUKON mass, water volume, blender operation setting, and preparation time to be as specified by the test engineer from previous R4 testing and recorded below.
Target R4 Value: _____.

Initial Preparation Parameters:

___ Obtain _____ grams of vendor supplied NUKON wool.
___ NUKON Lot # _____.
___ Moisture Content Reading _____. Oven prepared? yes ___ no ___
___ Put dry NUKON in blender.
___ Add _____ mL water.

Preparation:

Prepare the slurry in blender operated at setting _____. Measure the preparation time with a stopwatch.

Start blender within 1 minute of putting NUKON and water in blender.

___ Record total preparation time: _____ min _____ seconds
___ Pour prepared material into a container suitable for transporting material to test loop.
___ Use ~ 100 mL water to rinse out residual NUKON from blender into container.

Refer to Slurry Injection Procedure for further instruction.

Date: _____ Operator: _____ NUKON Slurry Name: _____
for Test No.: _____

CalSil Debris Preparation Procedure

Equipment needed:

Scale: Sartorius BP 3100 S or scale with similar accuracy.

Container to measure water volume with a scale sufficient to be able to differentiate ± 25 mL.

Blender used: _____. Use the provided lid that came with the blender.

Stop watch with the ability to differentiate seconds.

CalSil mass, water volume, blender operation setting, and preparation time to be as specified by the test engineer from previous R4 testing and recorded below.
Target R4 Value: _____.

Initial Preparation Parameters:

___ Obtain _____ grams of vendor supplied CalSil, breaking off irregularly shaped "chunks" of approximately 0.25 to 0.75 in diameter.
___ CalSil Lot # _____.
___ Moisture Content Reading _____. Oven prepared? yes ___ no ___
___ Put CalSil in blender.
___ Add _____ mL water.

Preparation:

Prepare the slurry in blender operated at setting _____. Measure the preparation time with a stopwatch.

Start blender within 1 minute of putting CalSil and water in blender.

___ Record total preparation time: _____ min _____ seconds
___ Pour prepared material into a container suitable for transporting material to test loop.
___ Use ~ 100 mL water to rinse out residual CalSil from blender into container.

Refer to Slurry Injection Procedure for further instruction.

Date: _____ Operator: _____ CalSil Slurry Name: _____
for Test No.: _____

Appendix F – Benchtop Test Results

Appendix F - Benchtop Test Results

Table F.1.1. Benchtop Test Results for 051214_NC_1234_B1

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.2[a]	26
0.13	948
0.16	986
0.14	870
0.09	671
0.05	440
0.1	728
0.16	946
0.1	634
0.03	305
0.1	683
0.17	945
0.1	671
0.04	309

(a) NUKON only debris bed.

Table F.1.2. Benchtop Test Results for 051214_NC_1234_B2

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.2[a]	24
0.075	789
0.045	536
0.077	789
0.107	965
0.075	750
0.043	494
0.078	770
0.101	963
0.078	751
0.045	480

(a) NUKON only debris bed.

Table F.1.3. Benchtop Test Results for 051215_NC_1234_B1

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.138	65
0.2	187
0.236	300
0.285	517
0.231	400
0.2	342
0.23	422
0.28	538
0.227	430
0.202	363
0.05	68

Table F.1.4. Benchtop Test Results for 051215_NC_1234_B2

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.21	109
0.25	126
0.34	323
0.4	537
0.242	267
0.19	193
0.27	350
0.33	507
0.283	409
0.2	247
0.283	421
0.332	542
0.284	436
0.199	261
0.05	42

Table F.1.5. Benchtop Test Results for 051216_NC_1234_B1

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.2	145
0.277	297
0.3	569
0.2	335
0.247	475
0.29	649
0.249	520
0.201	380
0.05	54

Table F.1.6. Benchtop Test Results for 051228_NC_1234_B1

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.035	972
0.021	351
0.037	880
0.02	309

Table F.1.7. Benchtop Test Results for 051228_NC_1234_B2

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.023	986
0.016	484
0.022	873
0.016	464

Table F.1.8. Benchtop Test Results for 051228_NC_1234_B3

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.006	975

Table F.1.9. Benchtop Test Results for 060207_NC_1234_B1

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.005	958

Table F.1.10. Benchtop Test Results for 060303_NC_1234_B2

Screen Approach Velocity (ft/sec)	Head Loss (in H_2O)
0.006	985

Appendix G – Screen-Only Quick Look Reports

Appendix G – Screen-Only Quick Look Reports

G.1 Quick-Look Report for PNNL Tests 051114_SO_0000_L1 and 051128_SO_0000_L1

This report conveys the head loss data collected in the PNNL large-scale test for the 5-mesh unloaded (no debris) screen. The data from Test 051114_SO-0000_L1 were taken with the 0–30-in. H_2O delta-pressure transmitter, while the data from Test 051128_SO-0000_L1 were taken with the 0–5-in. H_2O delta-pressure transmitter. The 0–5-in. H_2O delta-pressure transmitter has six times the resolution of the 0–30-in. H_2O transmitter and therefore provides a more accurate and stable response for conditions of relatively low head loss (i.e., < 10 in. H_2O).

At the highest tested screen approach velocity, 2.03 ft/sec, the head loss across the screen was approximately 2.2 in. H_2O (0–5 in. H_2O transmitter).

All data contained herein are preliminary. The data were obtained from manual recordings taken from visual observation of the DAS screen readouts. Testing was conducted in accordance with the specifications, plans, and limitations contained in correspondence *051108 NRC weekly notes.doc*. The test section inside diameter is 0.154 m (6.06 in.).

Table G.1.1 contains the test conditions and Table G.1.2 the screen dimensions. The preliminary data from both the 11/14/05 test using the 0–30-in. H_2O transmitter and the 11/28/05 test using the 0–5-in. H_2O transmitter are reported in Table G.1.3.

Table G.1.1. Test Conditions

Quick-Look Report Date	11/29/05
Date of tests	11/14/05 and 11/28/05
Associated test case(s)	N/A
Test number and data file reference	051114_SO_0000_L1 and 051128_SO_0000_L1
Target screen debris loading (g/m^2)	0.0
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	0.0
CalSil R4 target	N/A
Initial bed formation screen approach velocity (ft/sec)	N/A
Final bed formation screen approach velocity (ft/sec)	N/A
Bed formation time (min)	N/A
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	N/A
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) and U7 (2.3 L/Ds upstream of the test screen), D2 (10 L/Ds downstream of the test screen)
Dry Retrieved Debris Bed Mass (g)	N/A

Table G.1.2. Screen Dimensions

Material Description	Percentage of Open Area (%)	Dimensions of Open Area (in.^{2})	Center to Center Pitch of Open Areas (in.)
5-mesh woven wire screen	41	0.128	0.200

Table G.1.3. Preliminary Data

Test Date	Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)	Fluid Temperature (°C)
11/14/05[a]	Rampup (U1, D2)	0.26	0.0	17
11/14/05[a]	Rampup	0.46	0.0	17
11/14/05[a]	Rampup	0.92	0.2	17
11/14/05[a]	Rampup	1.28	0.4	17
11/14/05[a]	Rampup	1.52	0.7	17
11/14/05[a]	Rampup	1.75	0.9	19
11/14/05[a]	Rampup	2.02	1.5	21
11/14/05[a]	Ramp down (U7, D2)	1.77	1.2	22
11/14/05[a]	Ramp down	1.51	0.9	23
11/14/05[a]	Ramp down	1.25	0.5	23
11/14/05[a]	Ramp down	0.91	0.3	23
11/14/05[a]	Ramp down	0.52	0.1	24
11/14/05[a]	Ramp down	0.27	0.0	24
11/28/05[b]	Rampup (U1, D2)	0.22	0.0	16
11/28/05[b]	Rampup	0.50	0.0	16
11/28/05[b]	Rampup	0.75	0.2	17
11/28/05[b]	Rampup	1.02	0.7	17
11/28/05[b]	Rampup	1.53	1.2	17
11/28/05[b]	Rampup	1.73	1.6	18
11/28/05[b]	Rampup	2.03	2.2	18
11/28/05[b]	Ramp down (U1, D2)	1.73	1.6	19
11/28/05[b]	Ramp down	1.51	1.2	19
11/28/05[b]	Ramp down	1.25	0.8	19
11/28/05[b]	Ramp down	1.00	0.5	19
11/28/05[b]	Ramp down	0.75	0.2	19
11/28/05[b]	Ramp down	0.50	0.0	19

(a) Data taken with the 0–30-in. H_2O delta-pressure transmitter.
(b) Data taken with the 0–5-in. H_2O delta-pressure transmitter.

G.2 Quick-Look Report for PNNL Tests 060804_PO_0000_L1, 060804_PO_0000_L2, and 060805_PO_0000_L1

This report conveys the head loss data collected in the PNNL large-scale test for the perforated plate with 1/8-in.-diameter holes, unloaded (no debris) plate. All of the data from Tests 060804_PO_0000_L1 and 060804_PO_0000_L2 were taken with the 0–5-in. H_2O delta-pressure transmitter, while some of the data from Test 060805_PO_0000_L1 were taken with the 0–30-in. H_2O delta-pressure transmitter. The increased loop temperature resulted in higher head loss readings due to the temperature difference between the loop and the fluid in the transmitter tubing. The 0–5-in. H_2O delta-pressure transmitter has six times the resolution of the 0–30-in. transmitter and therefore provides a more accurate and stable response for conditions of relatively low head loss (i.e., < 5 in. H_2O).

At the highest tested screen approach velocity, 2.03 ft/sec, the head loss across the plate was approximately 3.7 in. H_2O for a reference temperature of 68°F.

All data herein are preliminary. The data were obtained from manual recordings taken from visual observation of the DAS screen readouts. Head loss measurements were obtained from visual observation of DAS screen using the 60-second-averaged meter readouts. The value reported is from the differential

pressure (DP) meter with the most appropriate span for the given range of head loss readings. Testing was conducted in accordance with the provided test plan (provided in a memo from CW Enderlin, PNNL, to WJ Krotiuk on April 4, 2006: *Plans for Conducting Debris-Bed Head Loss Tests in the PNNL Large-Scale Test Loop During April 2006*). The test section inside diameter is 0.154 m (6.06 in.).

The experimental measurements of head loss data are presented without zero offset or cold-leg–hot-leg temperature corrections applied, followed by the measurements of head loss with corrections applied. The maximum attainable temperature difference between the DP "legs" during testing is approximately 82° to 21°C. This temperature difference equates to approximately 5 in. H_2O assuming each leg is filled with water of different temperatures. Data uncertainties will be elucidated in the final report.

The test loop temperature was different for each test. Nominal loop temperatures of 81°F (27°C), 129°F (54°C), and 180°F (82°C) were used for tests 060804_PO_0000_L1, 060804_PO_0000_L2, and 060805_PO_0000_L1, respectively. Because of the relatively low flow rate of the loop and the centralized location of the band heaters, the uncertainty of the nominal loop temperature throughout the tests is ± 5°F (2.8°C).

Table G.2.1 contains the test conditions; the plate dimensions are presented in Table G.2.2. The preliminary experimental head loss data for all three tests are listed in Table G.2.3, and the preliminary measurements of head loss with temperature and zero corrections applied in Table G.2.4. The corrected measurements of head loss are plotted as a function of screen approach velocity in Figure G.2.1 without error bars and in Figure G.2.2 with the error bars.

Table G.2.1. Test Conditions

Quick-look report date	8/6/06
Date of tests	8/4/06 and 8/5/06
Associated test case(s)	Series 1 Screen Only 051114_SO_0000_L1 051128_SO_0000_L1 Series 2, Priority 13
Test number and data file reference	060804_PO_0000_L1, 060804_PO_0000_L2 060805_PO_0000_L1
Target screen debris loading (g/m^2)	0.0
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	0.0
CalSil R4 target	N/A
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	N/A
Final bed formation screen approach velocity (ft/sec)	N/A
Bed formation time (min)	N/A
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	N/A
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	N/A

Table G.2.2. Perforated Plate Dimensions

Material Description	Percentage of Open Area (%)	Dimensions of Open Area (in.)	Center to Center Pitch of Open Areas (in.)
Perforated metal plate with hexagonal hole pattern	40	0.125 I.D. round	0.188

Table G.2.3. Preliminary Measurements[a]

Test Phase	Screen Approach Velocity (ft/sec)	060804_PO_0000_L1 Nominal temp. 81°F (27°C)		060804_PO_0000_L2 Nominal temp. 129°F (54°C)		060805_PO_0000_L1 Nominal temp. 180°F (82°C)	
		Head Loss[b] (in. $(H_2O)^2$	Average Loop Temp. (°C)	Head Loss[b] (in $H_2O)^2$	Average Loop Temp. (°C)	Head Loss[b] (in $H_2O)^2$	Average Loop Temp. (°C)
Instrument Zero	0.00	0.07	26	0.07	53	0.05	80
System zero	0.00	0.13	26	1.31	54	3.24	81
Rampup 1	0.02	0.1	26	1.2	53	3.1	80
Rampup 1	0.05	0.1	26	1.2	54	3.1	79
Rampup 1	0.10	0.1	26	1.2	53	3.1	84
Rampup 1	0.20	0.1	26	1.3	55	3.1	80
Rampup 1	0.30	0.1	26	1.3	54	3.4	67
Rampup 1	0.50	0.3	26	1.6	55	3.5	82
Rampup 1	0.75	0.6	26	1.9	55	3.9	83
Rampup 1	1.00	1.0	26	2.3	55	4.3	83
Rampup 1	1.25	1.6	27	2.7	55	4.8	83
Rampup 1	1.50	2.4	27	3.8	55	5.4	84
Rampup 1	1.75	3.2	28	4.3	56	6.3	84
Rampup 1	2.00	3.9	29	4.8	56	6.6	85
Instrument zero	0.00	0.01	29	0.07	54	0.05	81
System zero	0.00	0.16	29	1.37	55	3.30	80
Ramp down 1	2.00	3.9	29	4.7	57	6.5	80
Ramp down 1	1.75	3.2	30	4.4	57	6.1	82
Ramp down 1	1.50	2.4	30	3.8	56	5.4	84
Ramp down 1	1.25	1.6	30	2.8	56	4.8	84
Ramp down 1	1.00	1.2	30	2.3	56	4.4	83
Ramp down 1	0.75	0.7	30	1.9	56	3.9	82
Ramp down 1	0.50	0.4	30	1.6	56	3.5	82
Ramp down 1	0.30	0.3	30	1.4	55	3.3	81
Ramp down 1	0.20	0.2	30	1.4	55	3.3	81
Ramp down 1	0.10	0.2	30	1.3	55	3.3	81
Ramp down 1	0.05	0.2	30	1.3	55	3.2	81
Ramp down 1	0.02	0.2	30	1.3	55	3.2	81
Instrument zero	0.00	0.05	29	0.05	53	0.05	78
System zero	0.00	0.17	29	1.25	54	3.10	78

(a) DP meters online during testing: 0–30, 0–150, and 0–750 in. H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) The units inches H_2O are for a reference temperature of 68°F (20°C).

Table G.2.4. Preliminary Data with Zero Offset and Temperature Corrections Applied

Test Phase	Screen Approach Velocity (± 0.03 ft/sec)	Head Loss[(a)] for Test 060804_PO_0000_LP1 Nominal temp. 81°F (27°C) (± 0.1 in. (H_2O)[(b)]	Head Loss(a)[1] for Test 060804_PO_0000_LP2 Nominal temp. 129°F (54°C) (± 0.2 in. (H_2O)[(b)]	Head Loss[(a)] for Test 060805_PO_0000_LP1 Nominal temp. 180°F (82°C) (± 0.2 in. (H_2O)[(b)]
Rampup 1	0.02	-0.1	-0.1	-0.2
Rampup 1	0.05	-0.1	-0.1	-0.2
Rampup 1	0.10	-0.1	-0.2	-0.2
Rampup 1	0.20	-0.1	0.0	-0.2
Rampup 1	0.30	0.0	0.0	0.1
Rampup 1	0.50	0.1	0.2	0.3
Rampup 1	0.75	0.4	0.6	0.6
Rampup 1	1.00	0.9	1.0	1.1
Rampup 1	1.25	1.4	1.4	1.5
Rampup 1	1.50	2.2	2.5	2.2[(c)]
Rampup 1	1.75	3.0	3.0	3.1[(c)]
Rampup 1	2.00	3.7	3.5	3.4[(c)]
Ramp down 1	2.00	3.7	3.4	3.3[(c)]
Ramp down 1	1.75	3.1	3.0	2.9[(c)]
Ramp down 1	1.50	2.3	2.4	2.1[(c)]
Ramp down 1	1.25	1.5	1.5	1.5
Ramp down 1	1.00	1.0	1.0	1.1
Ramp down 1	0.75	0.6	0.6	0.6
Ramp down 1	0.50	0.3	0.3	0.3
Ramp down 1	0.30	0.1	0.1	0.1
Ramp down 1	0.20	0.1	0.1	0.0
Ramp down 1	0.10	0.0	0.0	0.0
Ramp down 1	0.05	0.0	0.0	0.0
Ramp down 1	0.02	0.0	0.0	-0.1

(a) DP meters online during testing: 0–30, 0–150, and 0–750 in. H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) The units in. H_2O are for a reference temperature of 68°F (20°C).
(c) Measurements were made with the 0–30-in. transmitter, resulting in an increased uncertainty of ± 0.3 in. H_2O @ 68°F.

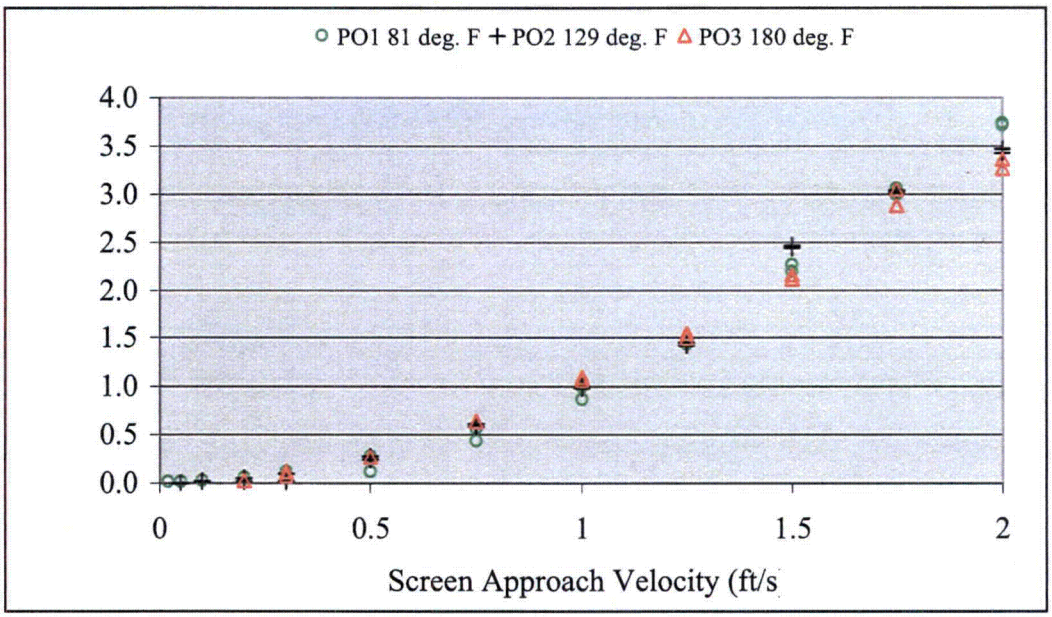


Figure G.2.1. Comparison of Head Loss Across the Bare Perforated Plate with 1/8-in. Holes as a Function of Approach Velocity for Nominal Temperatures of 81°, 129°, and 180°F Without Error Bars

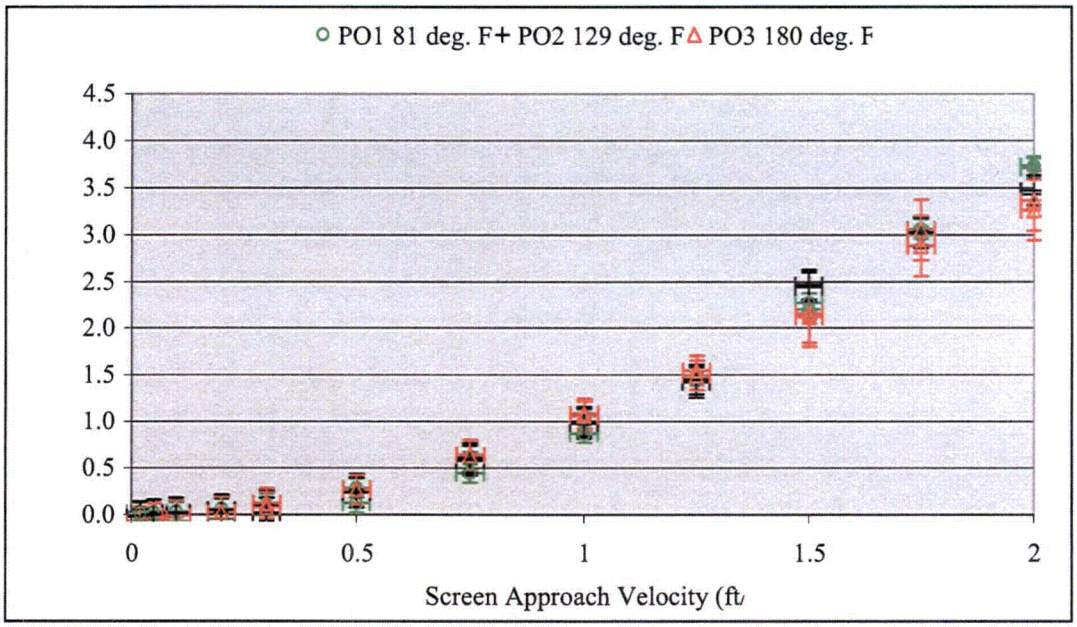


Figure G.2.2. Comparison of Head Loss Across the Bare Perforated Plate with 1/8-in. Holes as a Function of Approach Velocity for Nominal Temperatures of 81°, 129°, and 180°F with Error Bars

Appendix H – NUKON Only Quick Look Reports

Appendix H – NUKON Only Quick Look Reports

H.1 Quick-Look Report for PNNL Test 060321_NO_0405_LP1, Test Condition BM-1, Preliminary PNNL Head Loss Test Data

This report conveys preliminary data from the PNNL large-scale test loop using Test Condition BM-1. This report will be updated to include in situ during-test debris bed thickness measurements from the optical triangulation system.

All data contained herein are preliminary. The data were obtained from manual recordings taken from visual observation of the data acquisition system (DAS) screen readouts. Head loss measurements were obtained from visual observation of DAS screen using the 60 sec averaged meter readout. The value reported is from the differential pressure (DP) meter with the most appropriate span for the given range of head loss readings. Testing was conducted in accordance with *Test Plan for Comparison Benchmark Testing of PNNL and ANL Test Loops Used to Measure Debris Bed Head Loss for Reactor Sump Pump Screens*. The test section inside diameter is 0.154 m (6.06 in.).

The debris bed formed had a raised annular ring of material against the wall of the test section that was thicker than the body of the debris bed and is referred to as the *rim*. During testing, the height of the rim is a direct measurement taken at the wall of the test section. The height of the body of the debris bed was estimated by visually observing and measuring the elevation above the screen at which a difference in the backlighting was observed showing through the rim. These measurements are referred to as *manual*. Manual measurements of the debris-bed body are not always obtainable because a difference in back-lighting is not always observed. In situ debris bed height measurements were also taken using optical triangulation.

Table H.1.1 lists the test conditions. Manual debris bed height measurements are reported in Table H.1.2 and Figure H.1.1. The top of the perforated plate assembly support ring was used as the reference datum to obtain the debris bed height measurements under flow conditions. The actual top of the perforated plate is approximately 0.0625 in. below this datum. Therefore, 0.0625 in. has been added to the reported measurements. The test apparatus during testing is shown in Figure H.1.2.

Post-retrieval debris bed height measurements on bed retrieval were not made because the bed was disturbed during retrieval, as shown in Figure H.1.3. The determination of the debris bed height from the optical triangulation technique is made by post-test analysis of digital photographs taken of the debris bed during the test. A series of evenly spaced parallel lines are projected onto debris bed surface, and digital pictures are taken at a known fixed angle. These images are compared with those taken with the same line projection on known calibrated surfaces.

The debris bed height determined from the optical triangulation debris bed height measurements are reported in Table H.1.3. These data represent the points currently analyzed; additional points for evaluation are available. The Picture/Test Condition denotes the test date, the loop, perforated plate and test number in that loop on that date, screen approach velocity, picture number from camera, and test phase with respect to the velocity matrix.

Table H.1.1. Test Conditions

Quick-Look report date	3/27/06
Date of test	3/21/06
Associated test case(s)	ANL BM-1
Test number and data file reference	060321_NO_0405_LP1
Sump screen material installed in test section	Perforated plate; 1/8-in. ports, 3/16-in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	217
Initial NUKON mass introduced (g)	4.05
NUKON R4 target and water dilution	16.3 for 1000 mL water dilution (for comparison, see *R4 pour tests, update3.14.06.doc*, ANL)
Initial CalSil mass introduced (g)	0.0
CalSil R4 target	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	185
Calculated number of representative circulations during debris bed formation	20
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	3.18[a]

(a) Debris bed disturbed post-test during retrieval; visual observation indicated negligible debris material loss from disturbance.

Table H.1.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss[a,b] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)[c]	
Bed formation	0.10	3.4	0.22	-	21
Ramp down 1	0.10	3.5	0.14	-	21
Ramp down 1	0.05	1.7	0.18	-	21
Ramp down 1	0.02	0.5	0.18	-	21
Rampup 1	0.05	1.6	0.20	-	21
Rampup 1	0.10	3.7	0.14	-	21
Ramp down 2	0.05	1.8	0.14	-	22
Ramp down 2	0.02	0.6	0.18	-	21
Rampup 2	0.10	3.9	0.18	-	21
Rampup 2	0.15	6.6	0.14	-	21
Rampup 2	0.20	9.2	0.16	-	21
Ramp down 3	0.15	7.3	0.18	-	21
Ramp down 3	0.10	4.6	0.18	-	21
Rampup 3	0.15	7.6	0.14	-	21
Rampup 3	0.20	10.6	0.18	-	21
Ramp down 4	0.10	5.5	0.18	-	21
Ramp down 4	0.05	2.3	0.18	-	21
Ramp down 4	0.02	0.8	0.18	-	21
Rampup 4	0.10	5	0.18	-	21

(a) DP meters online during testing: 0–5, 0–30, and 0–150 in. H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) Measurements taken after increase of loop static pressure (~2.5 atm).
(c) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation of the screen at which a different amount of backlight showed through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.

Table H.1.3. In Situ Debris Bed Measurements

Optical Triangulation Debris Bed Measurements						
Picture/Test Condition	Height (in.)			Diameter (in.)	Volume (in.^{3})	
	Rim	Body Center	Average Body	Body	Body	Total Debris Bed
--	TBD	--	--	--	--	--
--	--	--	--	--	--	--
--	--	--	--	--	--	--
--	--	--	--	--	--	--
--	--	--	--	--	--	--
--	--	--	--	--	--	--

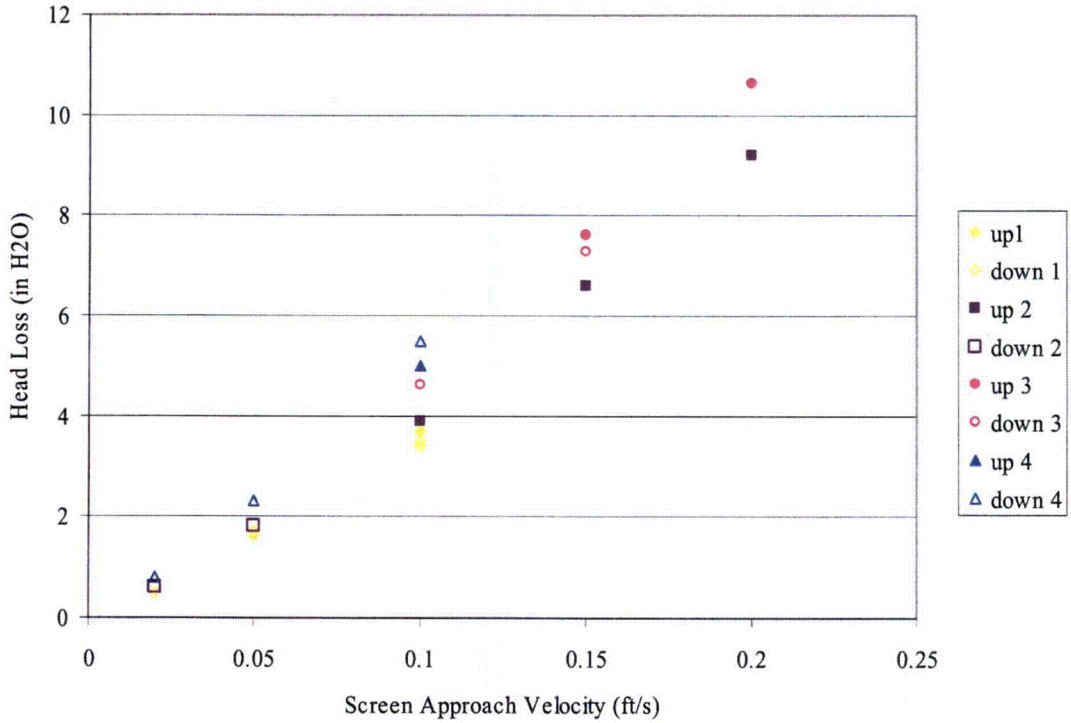


Figure H.1.1. Preliminary PNNL Data; 060321_NO_0405_LP1

Figure H.1.2. Submerged 060321_NO_0405_LP1 Debris Bed During the Test

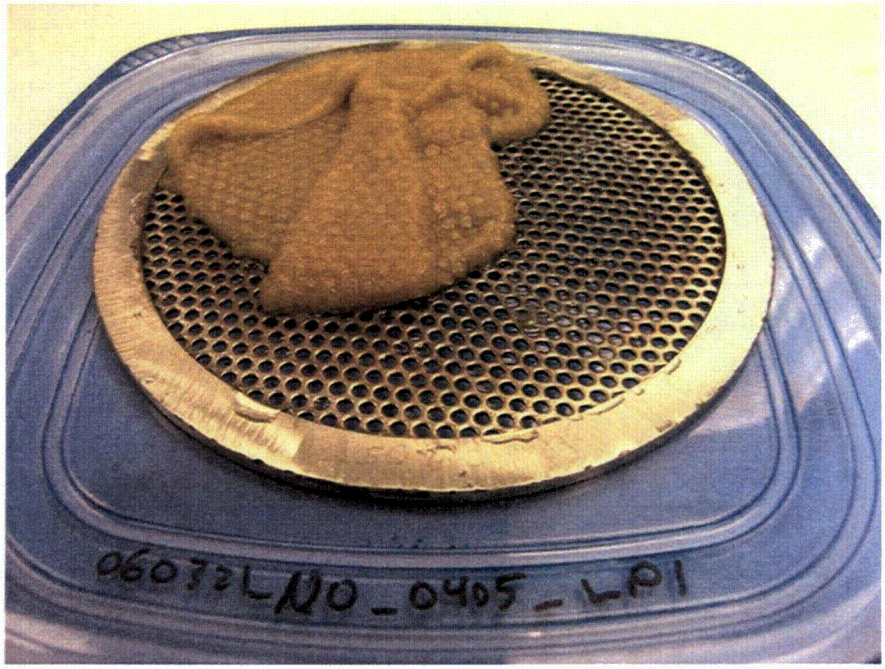


Figure H.1.3. 060321_NO_0405_LP1 Debris Bed After Retrieval. The disturbance consisted of the entire debris bed floating up under severely reduced flow conditions, flipping over and folding up, and then re-depositing on the plate once flow was increased. The debris bed was visually observed to remain essentially intact.

H.2 Quick-Look Report for PNNL Test 060313_NO_1349_LP1, Test Condition BM-2 Preliminary PNNL Head Loss Test Data

This report conveys preliminary data from the PNNL large-scale test loop Test Condition BM-2. This report will be updated to include in situ during-test debris bed thickness measurements from the optical triangulation system.

All data herein are preliminary. The data were obtained from manual recordings taken from visual observation of the DAS screen readouts. Head loss measurements obtained from visual observation of DAS screen using the 60-second-averaged meter readout. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings. Testing was conducted in accordance with *Test Plan for Comparison Benchmark Testing of PNNL and ANL Test Loops Used to Measure Debris Bed Head Loss for Reactor Sump Pump Screens*. The test section inside diameter is 0.154 m (6.06 in.).

The debris bed formed had a raised annular ring of material against the wall of the test section that was thicker than the body of the debris bed and is referred to as the "rim." During testing, the height of the rim is a direct measurement taken at the wall of the test section. The height of the body of the debris bed was estimated by visually observing and measuring the elevation above the screen at which a difference in the backlighting showing through the rim was observed. These measurements are referred to as "manual." In situ debris bed height measurements were also taken using optical triangulation.

Table H.2.1 contains the test conditions. Manual debris bed height measurements are reported in Table H.2.2 and Figure H.2.1. The top of the perforated plate assembly support ring was used as the reference datum to obtain the debris bed height measurements under flow conditions. The actual top of the perforated plate is approximately 0.0625 in. below this datum. Therefore, 0.0625 in. has been added to the reported measurements.

Post-retrieval debris bed height measurements taken upon bed retrieval are provided in Table H.2.3. The test bed after retrieval is shown is Figures H.2.2 through H.2.4. The determination of the debris bed height from the optical triangulation technique is made by post-test analysis of digital photographs taken of the debris bed during the test. A series of evenly spaced parallel lines are projected onto debris bed surface. Digital pictures are then taken at a known fixed angle and the images compared with those taken with the same line projection on known calibrated surfaces.

The debris bed height determined from the optical triangulation debris bed height measurements are reported in Table H.2.4. These data represent the points currently analyzed; additional points for evaluation are available. The picture/test condition denotes the test date (060313), the loop, perforated plate and test number in that loop on that date (L for PNNL large scale, P for perforated plate, and 1 for first test), screen approach velocity (0.1 ft/sec, 0.2 ft/sec, etc.), picture number from camera, and test phase (RU1 for first rampup, RD1 for first ramp down, etc.).

Table H.2.1. Test Conditions

Quick-look report date	3/14/06
Date of test	3/13/06
Associated test case(s)	ANL BM-2
Test number and data file reference	060313_NO_1349_LP1
Sump screen material installed in test section	Perforated plate, 1/8-in. ports, 3/16-in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	724
Initial NUKON mass introduced (g)	13.49
NUKON r4 target and water dilution	20.0 for 2500 mL water dilution 10.8 for 1000 mL water dilution (see *060310 Benchmark R4 Memo.doc*)
Initial CalSil mass introduced (g)	0.0
CalSil r4 target	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	160
Calculated number of representative circulations during debris bed formation	20
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	10.74

Table H.2.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss[a,b] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim (in.)	Estimated Body[c] (in.)	
Bed formation	0.10	8.6[b]	0.65	-	19
Ramp down 1	0.10	8.6[b]	0.65	-	19
Ramp down 1	0.05	4.1	0.65	-	20
Ramp down 1	0.02	1.2	0.63	-	20
Rampup 1	0.05	4.4	0.58	-	20
Rampup 1	0.10	9.7	0.58	-	20
Ramp down 2	0.05	4.6	0.62	-	20
Ramp down 2	0.02	1.4	0.58	-	20
Rampup 2	0.10	10.0	0.60	-	20
Rampup 2	0.15	16.2	0.58	-	20
Rampup 2	0.20	23.5	0.58	-	20
Ramp down 3	0.15	16.8	0.58	-	20
Ramp down 3	0.10	11.3	0.58	-	21
Rampup 3	0.15	17.3	0.58	-	21
Rampup 3	0.20	25.2	0.58	-	21
Ramp down 4	0.10	12.1	0.58	-	21
Ramp down 4	0.05	4.9	0.58	-	21
Ramp down 4	0.02	1.6	0.58	-	21
Rampup 4	0.10	11.8	0.58	-	22

(a) DP meters online during testing: 0–30, 0–150, and 0–750-in. H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) Before increase of loop static pressure (~2.5 atm).
(c) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation at which there was a different amount of backlight showing through the rim. Blank (-) entries indicate that no measurement was taken because no difference was observed in backlighting.

Table H.2.3. Post-Retrieval Manual Debris Bed Measurements

Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.57	0.19	6.06	5.51

Table H.2.4. In Situ Debris Bed Measurements

Optical Triangulation Debris Bed Measurements						
Picture/Test Condition	Height (in)			Diameter (in)	Volume (in^3)	
	Rim	Body Center	Average Body	Body	Body	Total Debris Bed
060313_LP1_0.1_27_RD1	TBD	--	--	--	--	--
060313_LP1_0.02_30_RD1	--	--	--	--	--	--
060313_LP1_0.2_37_RU2	--	--	--	--	--	--
060313_LP1_0.2_42_RU3	--	--	--	--	--	--
060313_LP1_0.02_45_RD4	--	--	--	--	--	--
060313_LP1_0.1_47_RU4	--	--	--	--	--	--

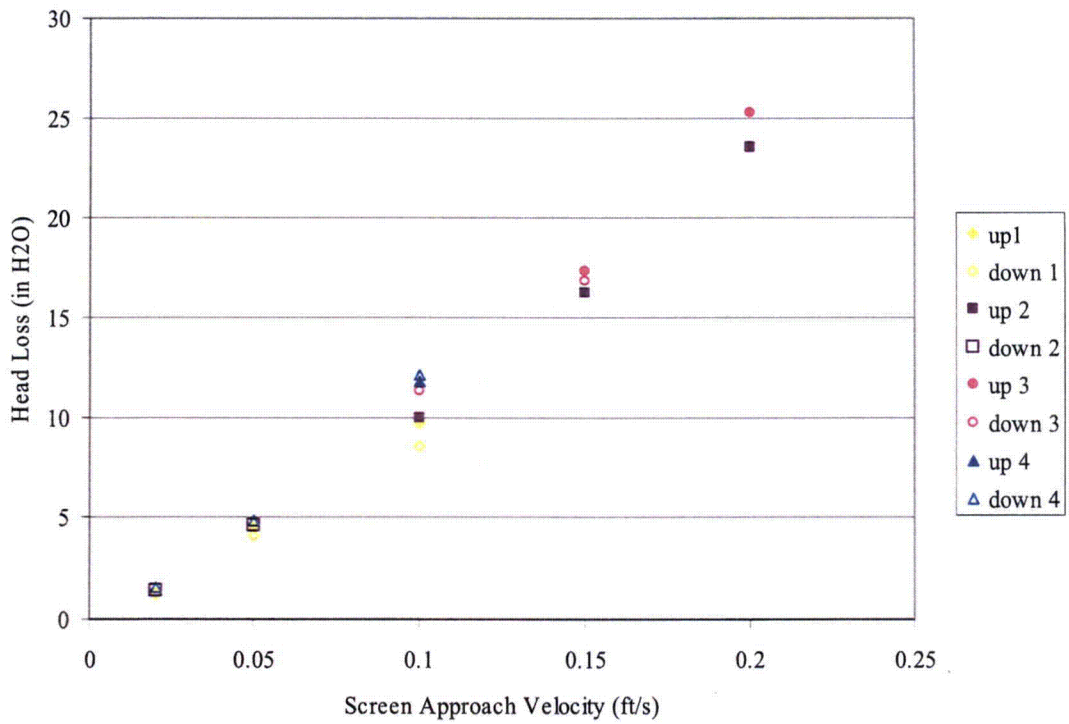


Figure H.2.1. Preliminary PNNL Data, 060313_NO_1349_LP1

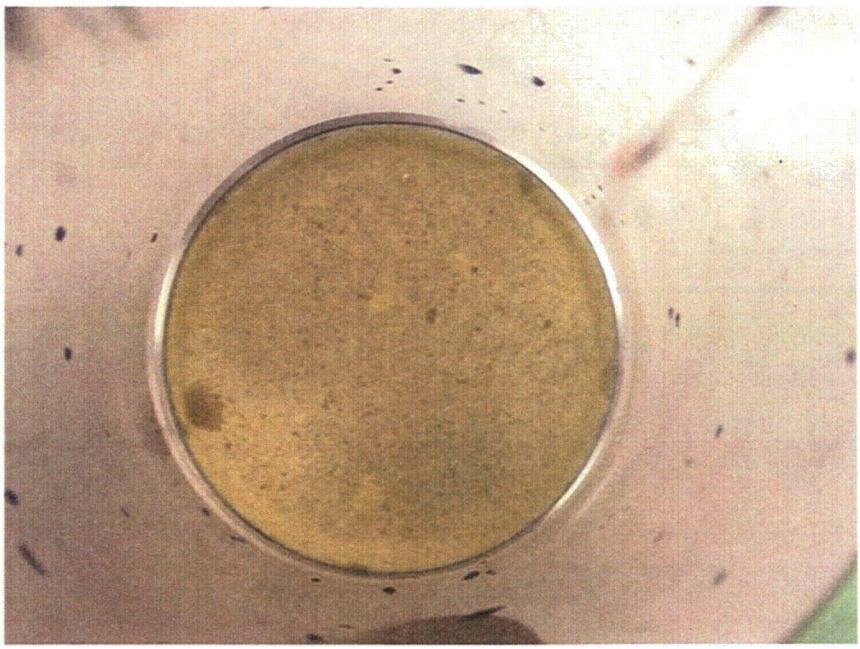


Figure H.2.2. 060313_NO_1349_LP1 Debris Bed in Test Section After Retrieval, Top View

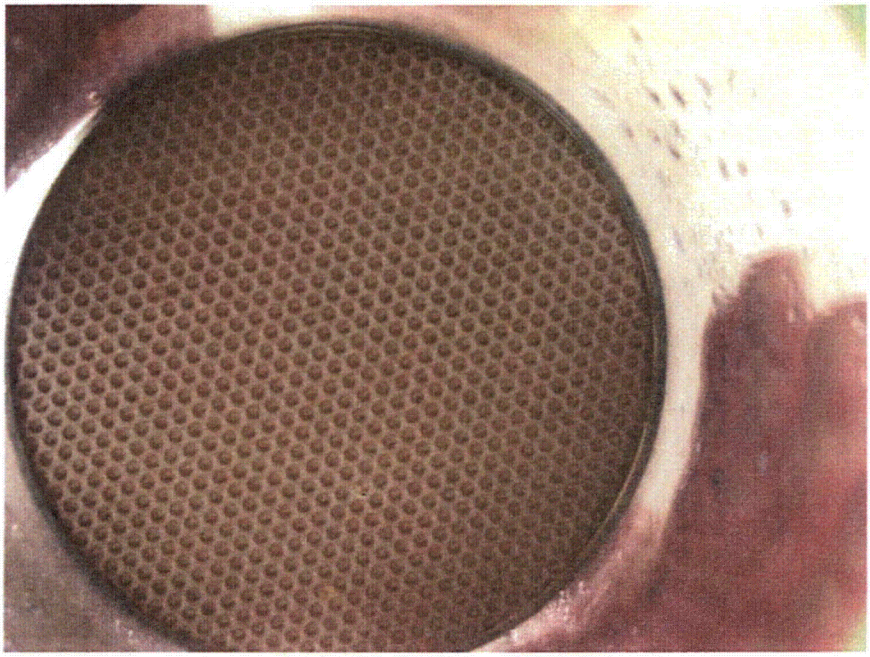


Figure H.2.3. 060313_NO_1349_LP1 Debris Bed in Test Section After Retrieval, Bottom View

Figure H.2.4. 060313_NO_1349_LP1 Debris Bed After Retrieval from Test Section

H.3 Quick-Look Report for PNNL Tests 060425_NO_2703_LP1, 060425_NO_2703_LP2, and 060425_NO_2703_LP3, Test Condition Series II Priority 1, Preliminary PNNL Head Loss Test Data

This report conveys preliminary data from the PNNL large-scale test loop Test Condition Series II Priority 1. This report will be updated to include in situ during-test debris bed thickness measurements from the optical triangulation system.

All data herein are preliminary. Test conditions are reported in Table H.3.1 and preliminary test data in Tables H.3.2–H.3.4. The data were obtained from manual recordings of visual observation of the DAS screen readouts. Head loss measurements were obtained from visual observation of the DAS screen using the 60-second-averaged meter readouts. The value reported is from the DP meter with the most appropriate span for the given range of head loss readings. In Tables H.3.5–H.3.7, zero and cold-leg/hot-leg temperature corrections for the delta pressure transducers and associated manifold have been applied to the preliminary head loss data values. These corrections may not result in a change of the preliminary head loss data. The maximum attainable temperature difference between the DP legs during testing is approximately 82° to 21°C, which equates to approximately 5 in. H_2O assuming each leg is filled with water of a different temperature. Data uncertainties will be elucidated in the final report. Testing was conducted in accordance with the test plan, *Plans for Conducting Debris-Bed Head Loss Tests in the PNNL Large-Scale Test Loop During April 2006*. The test section inside diameter is 0.154 m (6.06 in.).

The debris bed formed had a raised annular ring, or rim, of material against the wall of the test section that was thicker than the body of the debris bed. During testing, the height of the rim is a direct measurement taken at the wall of the test section. The height of the body of the debris bed was estimated by visually observing and manually measuring the elevation above the screen at which a difference in the backlighting showing through the rim was observed.

Table H.3.1. Test Conditions

Quick-Look Report Date	5/24/06
Date of test	4/25/06
Associated test case(s)	Series II Priority 1
Test number(s) and data file reference(s)	060425_NO_2703_LP1 060425_NO_2703_LP2 060425_NO_2703_LP3
Sump screen material installed in test section	Perforated Plate. 1/8 in. ports, 3/16 in. center to center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	1450
Initial NUKON mass introduced (g)	27.03
NUKON R4 target	10 – 12
Initial CalSil mass introduced (g)	0.0
CalSil R4 target	N/A
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	60
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	7
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	23.19

Table H.3.2. Preliminary Data for Test 060425_NO_2703_LP1

Test Phase	Velocity (ft/sec)	Head Loss[a,b] (in H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim[c] (in.)	Estimated Body[d] (in.)	
Bed formation	0.10	25[2]	0.69	0.46	22
Rampup 1	0.10	26	0.69	-	22
Rampup 1 (pre filtering)	0.20	56	0.69	0.46	23
Rampup 1 (post-filtering)	0.20	59	0.69	0.46	23
Rampdown 1	0.10	27	0.69	0.46	23
Rampdown 1	0.05	12	0.69	0.46	23
Rampdown 1	0.02	3	0.69	0.46	23
Rampup 2	0.10	26	0.65	0.46	24
Rampup 2	0.20	60	0.65	0.46	24
Ramp down 2	0.10	27	0.69	0.46	24
Ramp down 2	0.02	3	0.73	0.46	24
Rampup 3	0.10	27	0.69	0.46	24
Rampup 3	0.20	60	0.65	0.46	24
Ramp down 3	0.10	27	0.65	0.46	24
Ramp down 3	0.02	3	0.69	0.46	25
Rampup 4	0.10	28	0.65	0.46	25

(a) DP meters online during testing: 0–30, 0–150, and 0–750 in. H_2O. The value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).
(c) The debris bed rim height varied by up to approximately 0.04 in. circumferentially for this test.
(d) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation of the screen at which a different amount of backlight showed through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.

Table H.3.3. Preliminary Data for Test 060425_NO_2703_LP2

Test Phase	Velocity (ft/sec)	Head Loss[a,b] (in H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim[b] (in.)	Estimated Body[c] (in.)	
Bed Formation	0.10	N/A	N/A	N/A	N/A
Rampup 1	0.10	29	0.69	-	53
Rampup 1 (pre filtering)	0.20	N/A	N/A	N/A	N/A
Rampup 1 (post-filtering)	0.20	68	0.69	0.46	53
Ramp down 1	0.10	29	0.65	-	53
Ramp down 1	0.05	12	0.65	0.46	53
Ramp down 1	0.02	4	0.69	0.46	54
Rampup 2	0.10	28	0.69	-	53
Rampup 2	0.20	66	0.69	-	53
Ramp down 2	0.10	29	0.65	-	53
Ramp down 2	0.02	3	0.73	-	53
Rampup 3	0.10	28	0.69	-	53
Rampup 3	0.20	68	0.65	-	52
Ramp down 3	0.10	30	0.65	-	53
Ramp down 3	0.02	3	0.69	-	52
Rampup 4	0.10	28	0.65	-	53

(a) DP meters online during testing: 0–30, 0–150, and 0–750 in. H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) The debris bed rim height varied by up to approximately 0.08 in. circumferentially for this test.
(c) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation of the screen at which a different amount of backlight showed through the rim. Blank (-) entries indicate that no measurement was taken because no difference in the backlighting was observed.

Table H.3.4. Preliminary Data for Test 060425_NO_2703_LP3

Test Phase	Velocity (ft/sec)	Head Loss[a,b] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim[b] (in.)	Estimated Body[c] (in.)	
Bed formation	0.10	N/A	N/A	N/A	N/A
Rampup 1	0.10	22	0.65	-	82
Rampup 1 (prefiltering)	0.20	N/A	N/A	N/A	N/A
Rampup 1 (post-filtering)	0.20	50	0.61	-	82
Ramp down 1	0.10	21	0.61	-	83
Ramp down 1	0.05	8	0.69	-	82
Ramp down 1	0.02	3	0.69	-	81
Rampup 2	0.10	20	0.69	-	84
Rampup 2	0.20	47	0.61	-	82
Ramp down 2	0.10	20	0.61	-	83
Ramp down 2	0.02	3	0.69	-	80
Rampup 3	0.10	19	0.65	-	83
Rampup 3	0.20	47	0.65	-	83
Ramp down 3	0.10	20	0.65	-	83
Ramp down 3	0.02	3	0.65	-	81
Rampup 4	0.10	21	0.65	-	76

(a) DP meters online during testing: 0 - 30, 0 – 150, and 0 – 750 in H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) The debris bed rim height varied by up to approximately 0.08 in circumferentially for this test.
(c) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation of the screen at which a different amount of backlight showed through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.

Table H.3.5. Corrected Data for Test 060425_NO_2703_LP1

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	25	22	22
Rampup 1	0.10	26	22	22
Rampup 1 (prefiltering)	0.20	56	23	22
Rampup 1 (post-filtering)	0.20	59	23	22
Ramp down 1	0.10	27	23	22
Ramp down 1	0.05	12	23	22
Ramp down 1	0.02	3	23	22
Rampup 2	0.10	26	24	22
Rampup 2	0.20	60	24	22
Ramp down 2	0.10	27	24	22
Ramp down 2	0.02	3	24	22
Rampup 3	0.10	27	24	22
Rampup 3	0.20	60	24	22
Ramp down 3	0.10	27	24	22
Ramp down 3	0.02	3	25	22
Rampup 4	0.10	28	25	22

Manual measurements of the debris-bed body are not always obtained because no difference in back-lighting may be observed. In situ debris bed height measurements were also taken using optical tri-angulation. The top of the perforated plate assembly support ring was used as the reference datum to obtain the debris bed height measurements under flow conditions. The actual top of the perforated plate is approximately 0.0625 in below the datum; thus 0.0625 in. was added to the reported measurements.

Table H.3.6. Corrected Data for Test 060425_NO_2703_LP2

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature(°C)
Bed Formation	0.10	#N/A	53	24
Rampup 1	0.10	28		
Rampup 1 (prefiltering)	0.20	#N/A	53	24
Rampup 1 (post-filtering)	0.20	67	53	24
Ramp down 1	0.10	28	53	24
Ramp down 1	0.05	11	54	24
Ramp down 1	0.02	3	53	24
Rampup 2	0.10	27	53	24
Rampup 2	0.20	65	53	24
Ramp down 2	0.10	28	53	24
Ramp down 2	0.02	2	53	24
Rampup 3	0.10	27	52	23
Rampup 3	0.20	67	53	23
Ramp down 3	0.10	29	52	23
Ramp down 3	0.02	2	53	23
Rampup 4	0.10	27	53	24

Table H.3.7. Corrected Data for Test 060425_NO_2703_LP3

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	#N/A		
Rampup 1	0.10	19	82	23
Rampup 1 (prefiltering)	0.20	#N/A		
Rampup 1 (post-filtering)	0.20	47	82	23
Ramp down 1	0.10	18	83	23
Ramp down 1	0.05	5	82	23
Ramp down 1	0.02	0	81	22
Rampup 2	0.10	17	84	26
Rampup 2	0.20	44	82	22
Ramp down 2	0.10	17	83	22
Ramp down 2	0.02	0	80	22
Rampup 3	0.10	16	83	22
Rampup 3	0.20	43	83	22
Ramp down 3	0.10	17	83	22
Ramp down 3	0.02	0	81	22
Rampup 4	0.10	18	76	21

Post-retrieval debris bed height measurements taken upon bed retrieval are provided in Table H.3.8. The test bed data before retrieval are depicted in Figures H.8 through H.10; the test bed after retrieval is shown in Figures H.11 through H.13.

The determination of the debris bed height from the optical triangulation technique is made by post-test analysis of digital photographs taken of the debris bed during the test. A series of evenly spaced parallel lines are projected onto debris bed surface. Digital pictures are then taken at a known fixed angle and these images are compared to those taken with the same line projection on known calibrated surfaces.

The debris bed height determined from the optical triangulation debris bed height measurements are reported in Table H.3.9. This data represents those points currently analyzed; additional points for evaluation are available. The picture/test condition denotes the test date, the loop, perforated plate and test number in that loop on that date, screen approach velocity, picture number from camera, and test phase with respect to the velocity matrix.

Table H.3.8. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	**Body Height (in.)**	**Total Bed Diameter (in.)**	**Body Diameter (in.)**
0.64	0.28	6.065	5.83

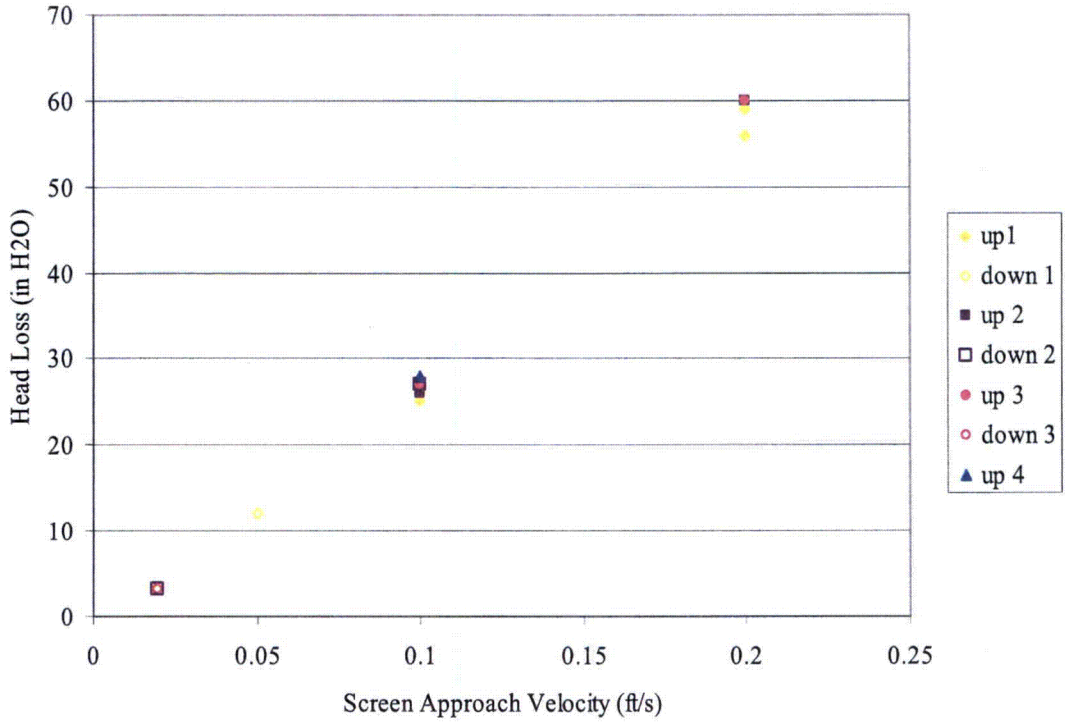


Figure H.3.1. Preliminary PNNL Data, 060425_NO_2703_LP1

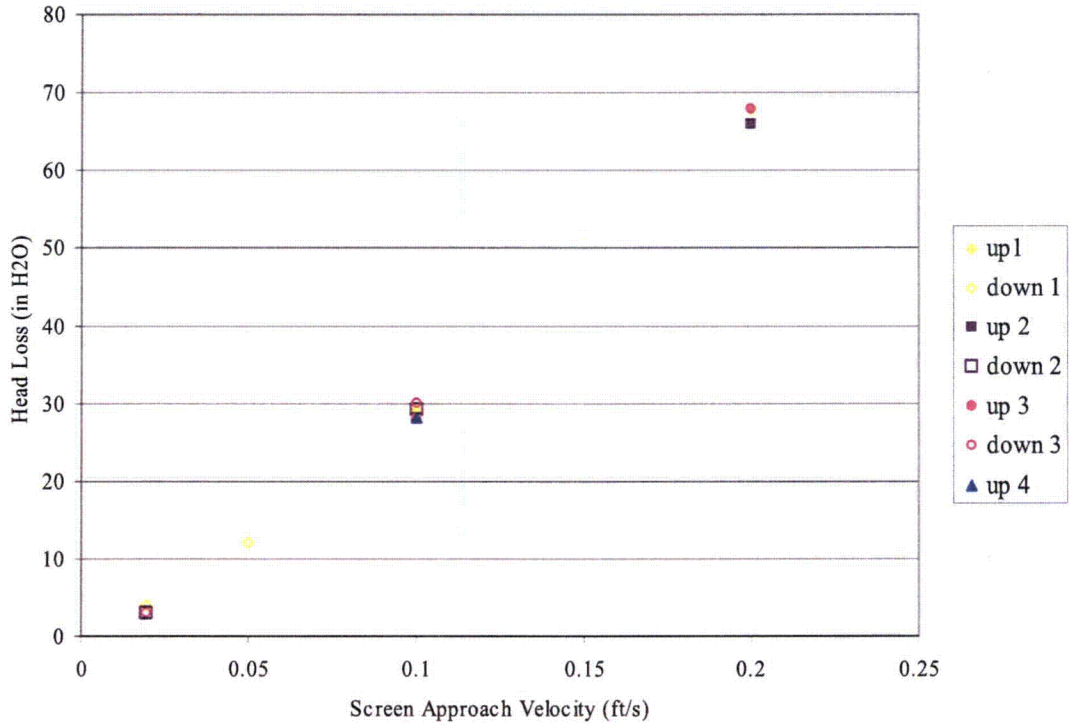


Figure H.3.2. Preliminary PNNL Data, 060425_NO_2703_LP2

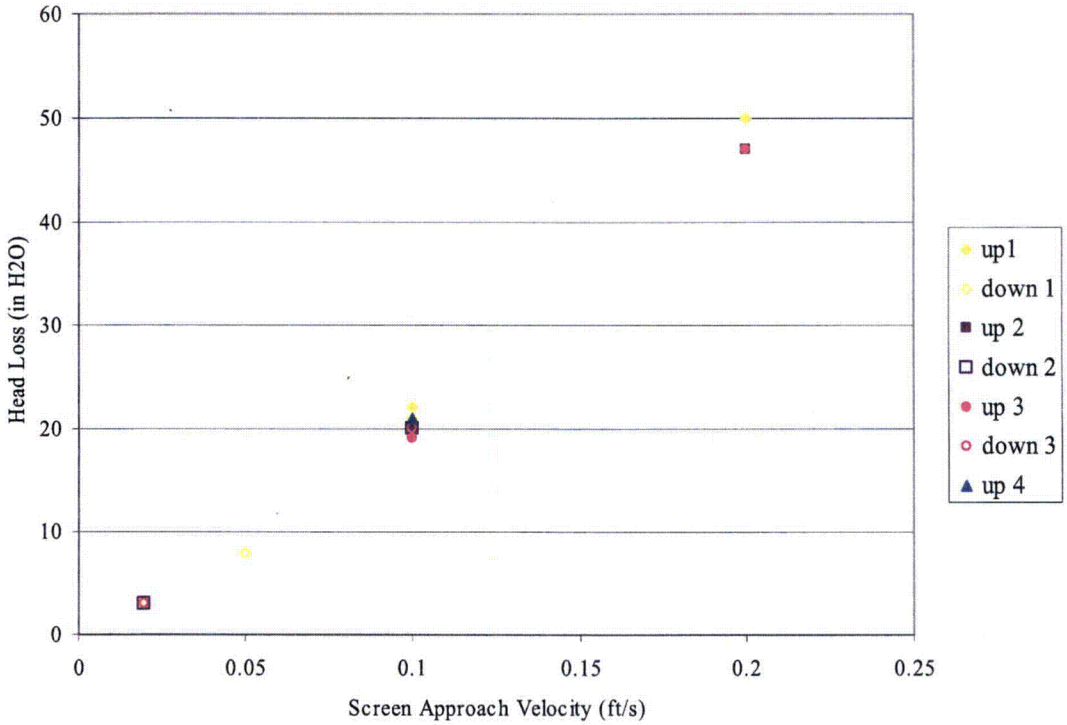


Figure H.3.3. Preliminary PNNL Data, 060425_NO_2703_LP3

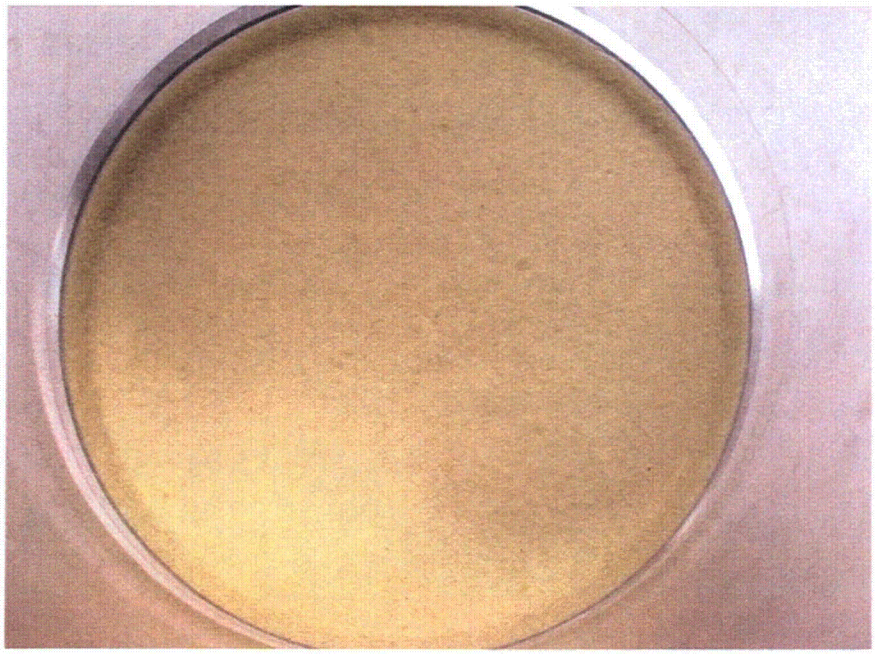


Figure H.3.4. 060425_NO_2703_LP1, LP2, LP3 Debris Bed in Test Section After Retrieval, Top View

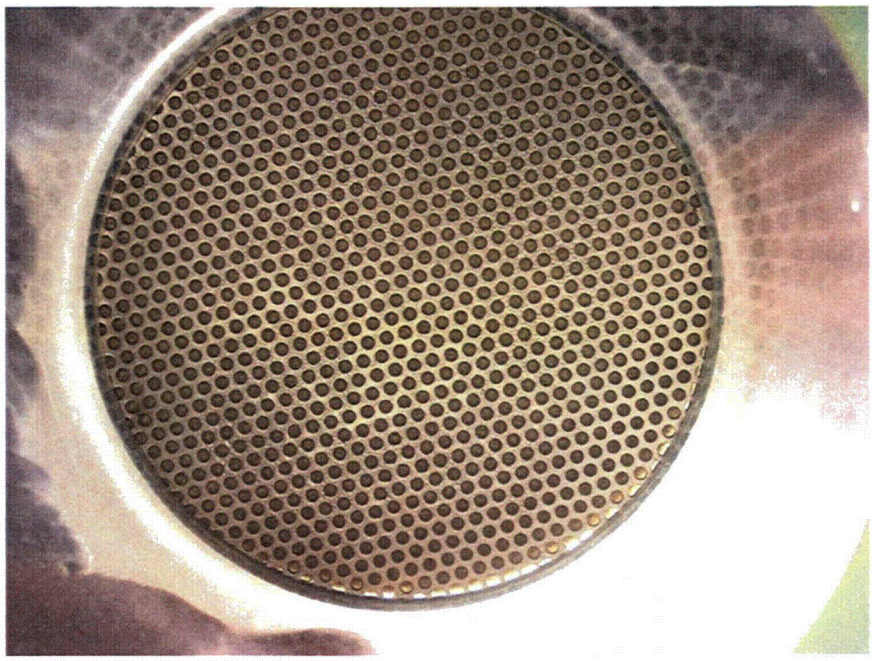


Figure H.3.5. 060425_NO_2703_LP1, LP2, LP3 Debris Bed in Test Section After Retrieval, Bottom View

Figure H.3.6. 060425_NO_2703_LP1, LP2, LP3 Debris Bed After Retrieval from Test Section

Table H.3.9. In Situ Debris Bed Measurement

Optical Triangulation Debris Bed Measurements						
	Height (in.)			Diameter (in.)	Volume (in.^{3})	
Picture/Test Condition	Rim	Body Center	Average Body	Body	Body	Total Debris Bed
060425_LP1_0.1_26_RU1	0.72	0.40	0.38	4.44	5.88	12.92
060425_LP1_0.2_28_RU1	0.66	0.35	0.33	4.54	5.34	11.33
060425_LP1_0.02_36_RD2	0.71	0.43	0.41	4.72	7.17	13.21
060425_LP1_0.1_37_RU3	0.64	0.37	0.35	4.72	6.13	11.46
060425_LP1_0.2_38_RU3	0.61	0.31	0.29	4.72	5.07	9.93
060425_LP1_0.1_39_RD3	0.61	0.35	0.33	4.98	6.42	10.57
060425_LP1_0.02_40_RD3	0.67	0.40	0.38	4.86	7.05	12.16
060425_LP1_0.1_41_RU4	0.62	0.34	0.32	4.88	5.99	10.48
060425_LP3_0.2_52_RU1	0.57	0.34	0.32	4.96	6.19	10.44
060425_LP3_0.02_55_RD1	0.66	0.42	0.40	4.84	7.37	12.92
060425_LP3_0.02_63_RD3	0.64	0.42	0.40	4.89	7.52	12.77

H.4 Quick-Look Report for PNNL Test 051108_NO_ 3067_L1, Test Condition LANL-1a Preliminary PNNL Head Loss Test Data

This report conveys preliminary data from the PNNL large-scale test loop. A graphical comparison of the preliminary large-scale results and those obtained in the PNNL benchtop loop for test conditions LANL-1a has been included. The debris bed was formed using an initial approach velocity of 0.2 ft/sec. The pump frequency was held constant and the approach velocity decreased as a result of the increasing head loss across the developing debris bed.

All data herein are preliminary and were obtained from manual recordings taken from visual observation of the DAS screen readouts. In Table H.4.3, zero and cold-leg/hot-leg temperature corrections for the delta pressure transducers and associated manifold have been applied to the preliminary head loss data values. These corrections may not result in a change of the preliminary head loss data. Testing was conducted in accordance with the specifications, plans, and limitations contained in correspondence *051108 NRC weekly notes.doc*. The test section inside diameter is 0.154 m (6.06 in.).

The debris beds formed typically had a raised annular ring of material against the wall of the test section that was thicker than the body of the debris bed and is referred to as the *rim*. The height of the rim is a direct measurement taken at the wall of the test section. The height of the body of the debris bed was estimated by visually observing and measuring the elevation above the screen at which a difference in the backlighting showing through the rim was observed.

Table H.4.1 contains test conditions. Manual debris bed height measurements are reported in Table H.4.2 and Figures H.4.1. Figure H.4.2 compares preliminary data to prior benchtop results. The top of the screen assembly support ring was used as the reference datum to obtain debris bed height measurements under flow conditions. The actual top of the screen is 0.06 to 0.08 in. below this datum; thus 0.06 in. was added to the reported measurements. Figure H.4.3 shows the test setup; Figures H.4.4 through H.4.6 show the debris bed after the test.

Table H.4.1. Test Conditions

Quick-look report date	11/9/05
Date of test	11/8/05
Associated test case(s)	LANL: 1a PNNL benchtop: 050803_NO_1363_1, 050815_NO_1363_1
Test number and data file reference	051108_NO_3067_L1
Target screen debris loading (g/m^2)	1681.4
Initial NUKON mass introduced (g)	30.67
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	0.0
CalSil R4 target	N/A
Initial bed formation screen approach velocity (ft/sec)	0.20
Final bed formation screen approach velocity (ft/sec	0.13
Bed formation time (min)	70
Calculated number of representative circulations during debris bed formation (from estimated 5-minute circulation time)	14
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	33.32[(a)]
(a) Metal/rust particulate from substitute gate valve is readily apparent on/in debris bed; see photographs, Figures H.4.4–H.4.6.	

From the measurements in Table H.4.4, the cross-sectional area of the debris bed body and annular rim may be computed as 24.72 and 4.12 $in.^2$, respectively. Assuming that the radial section of the rim is a right triangle, the rim volume is 0.76 $in.^3$. The fraction of the total debris bed volume contained in the rim is therefore 0.07.

Table H.4.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim (in.)	Estimated Body[b] (in.)	
Rampup 1	0.13	34[c]	-	-	20
	0.2	56[c]	-	-	20
	0.2	62	0.94	0.75	20
	0.4	139	0.81	0.53	21
	0.57	216	0.88	0.53	21
	0.7	285	0.69	0.44	21
	0.88	348	0.69	0.44	22
	0.97	388	0.69	0.41	24
Ramp down 1	0.88	345	0.69	0.44	24
	0.7	261	0.69	0.44	24
	0.56	199	0.66	0.44	25
	0.41	136	0.69	0.44	25
Rampup 2	0.2	61	0.69	0.44	25
	0.3	94	0.69	0.44	25
	0.41	137	0.69	0.44	25
	0.56	203	0.69	0.44	25
	0.71	276	0.69	0.44	25
	0.88	368	0.69	0.44	26
	0.96	410	0.69	0.44	26
Ramp down 2	0.88	370	0.69	0.44	27
	0.69	272	0.66	0.44	27
	0.56	206	0.66	0.44	27
	0.4	141	0.66	0.44	27
	0.29	96	0.66	0.44	27
	0.2	64	0.69	0.44	27
Rampup 3	0.3	103	0.66	0.44	27
	0.88	394	0.66	0.44	29
	0.96	438	0.66	0.44	30
Ramp down 3	0.87	386	0.66	0.44	30
	0.7	292	0.66	0.44	30
	0.41	154	0.66	0.44	30
	0.29	108	0.59	0.44	30
	0.2	72	0.63	0.44	29
Rampup 4	0.41	164	0.63	0.44	29
	0.7	314	0.63	0.44	29
	0.96	492	0.59	0.44	30
Ramp down 4	0.69	322	0.59	0.44	30
	0.41	170	0.63	0.44	30
	0.2	73	0.63	0.44	29
	0.1	32	0.63	0.44	29
	0.05	13	0.63	0.44	29
	0.02	4	0.69	0.44	29
Rampup 5	0.1	35	0.69	0.44	28
	0.2	80	0.66	0.44	28

(a) Head loss measurements are referenced to H_2O at 68^0F (20^0C).

(b) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation off the screen at which there was a difference in the amount of back-light which shown through the rim. Blank (-) entries indicate that no measurement was taken. Measurements taken upon bed retrieval are provided in Table H.4.4.

(c) Before the increase in loop static pressure (~2.5 atm).

Table H.4.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.13	34	20	20
	0.2	56	20	20
	0.2	62	20	20
	0.4	139	21	20
	0.57	216	21	20
	0.7	285	21	20
	0.88	348	22	20
	0.97	388	24	20
Ramp down 1	0.88	345	24	20
	0.7	261	24	20
	0.56	199	25	20
	0.41	136	25	20
Rampup 2	0.2	61	25	20
	0.3	94	25	20
	0.41	137	25	20
	0.56	203	25	20
	0.71	276	25	20
	0.88	368	26	20
	0.96	410	26	20
Ramp down 2	0.88	370	27	20
	0.69	272	27	20
	0.56	206	27	20
	0.4	141	27	20
	0.29	96	27	20
	0.2	64	27	20
Rampup 3	0.3	103	27	20
	0.88	394	29	20
	0.96	438	30	20
Ramp down 3	0.87	386	30	20
	0.7	292	30	20
	0.41	154	30	20
	0.29	108	30	20
	0.2	72	29	20
Rampup 4	0.41	164	29	20
	0.7	314	29	20
	0.96	492	30	20
Ramp down 4	0.69	322	30	20
	0.41	170	30	20
	0.2	73	29	20
	0.1	32	29	20
	0.05	13	29	20
	0.02	4	29	20
Rampup 5	0.1	35	28	20
	0.2	80	28	20

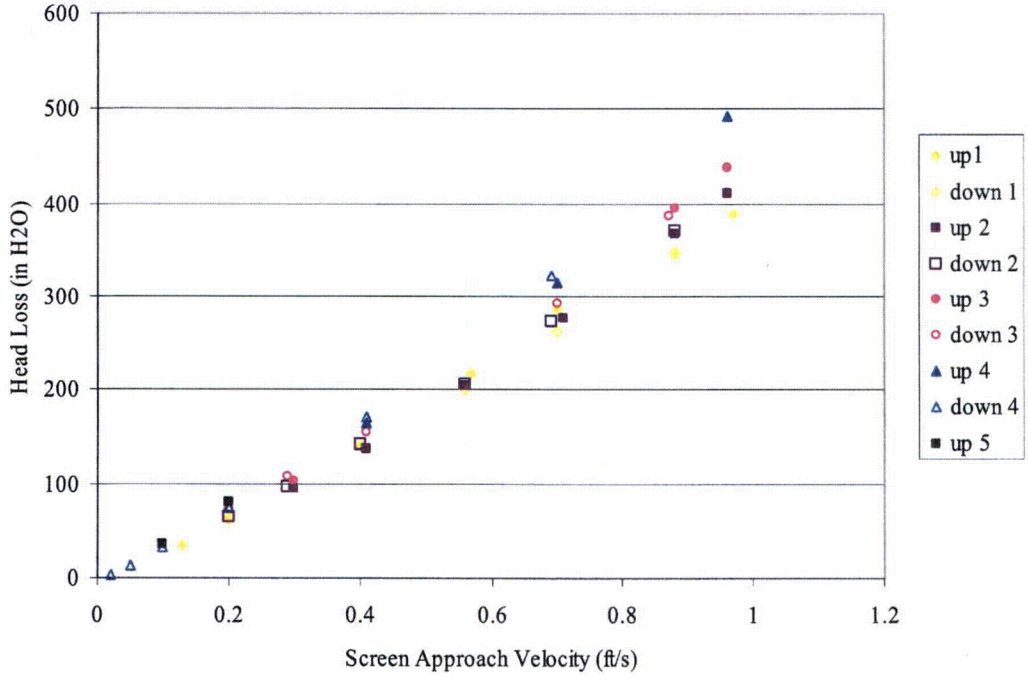


Figure H.4.1. Preliminary PNNL Data

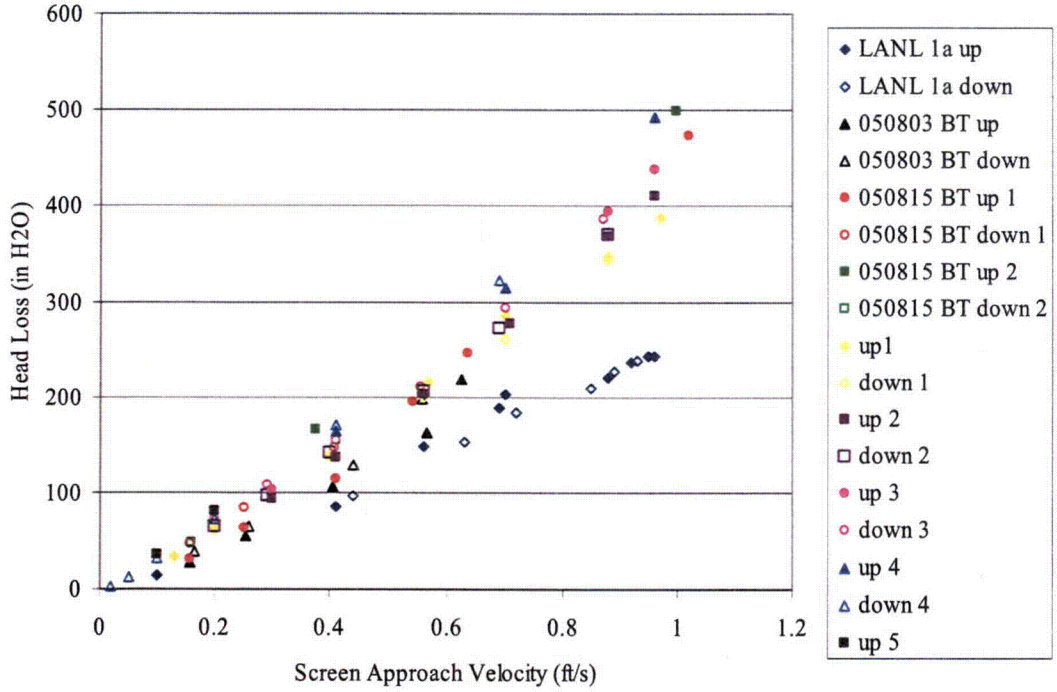


Figure H.4.2. Comparison of Preliminary PNNL Data with Previous Results (BT denotes PNNL benchtop)

Figure H.4.3. Submerged 051108_NO_3067_L1 Debris Bed During Test

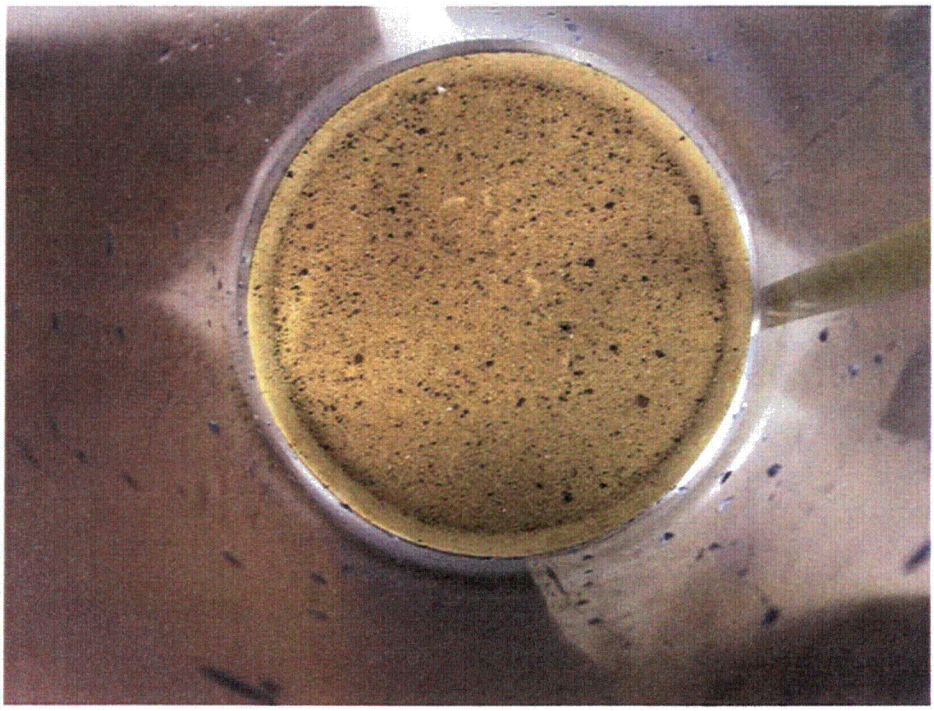


Figure H.4.4. 051108_NO_3067_L1 Debris Bed in Test Section After Retrieval, Top View

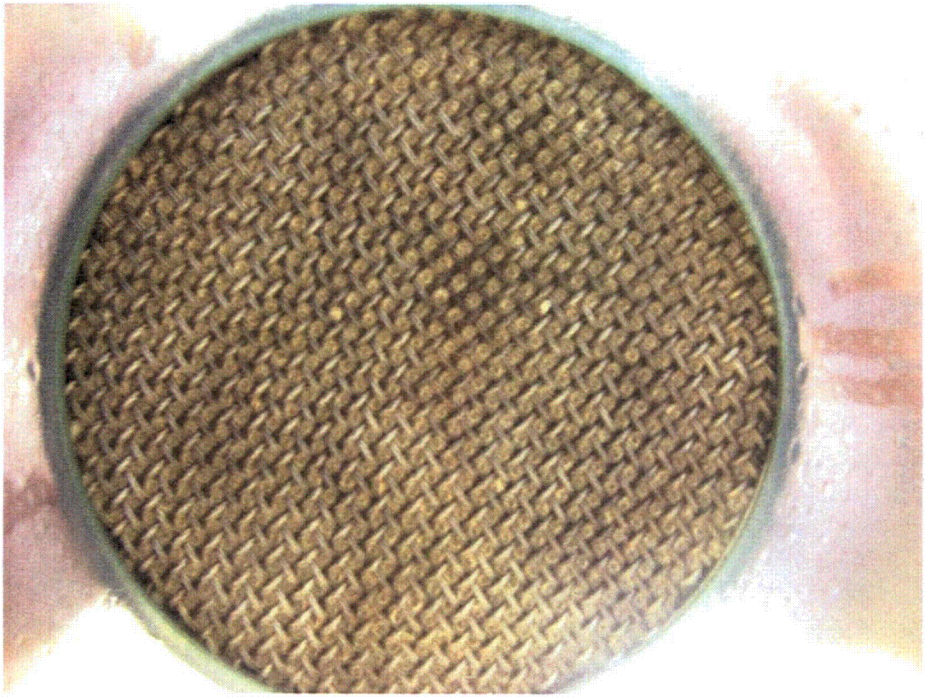


Figure H.4.5. 051108_NO_3067_L1 Debris Bed in Test Section After Retrieval, Bottom View

Figure H.4.6. 051108_NO_3067_L1 Debris Bed After Retrieval from Test Section

Table H.4.4. Post-Retrieval Debris Bed Measurements

Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.72	0.35	6.06	5.61

H.5 Quick-Look Report for PNNL Test 060125_NO_3067_L1, Test Condition LANL-1a, Repeatability Test, Preliminary PNNL Head Loss Test Data

This Quick-Look report conveys preliminary data from the PNNL large-scale test loop Test Condition LANL-1a repeatability test. This repeat test was conducted as an operational exhibit of the PNNL test loop for the January 25, 2006 visit of NRC Commissioner PB Lyons to PNNL. Included in this report are in situ during-test debris bed thickness measurements from the optical triangulation system. Contour plots of the debris bed thickness are also provided.

A comparison of repeatability is made with PNNL Test 051108_NO_3067_L1 preliminary large-scale results. Also included is a graphical comparison with the results previously obtained in the PNNL bench-top loop for the same test conditions as LANL-1a (all data previously presented in *Quick-Look Report for PNNL Test 051108_NO_ 3067_L1, Test Condition LANL-1a*).

To replicate the conditions of PNNL test 051108_NO_3067_L1, the debris bed was formed using an initial approach velocity of 0.2 ft/sec. The pump frequency was held constant and the approach velocity decreased as a result of the increasing head loss across the developing debris bed. (The majority of the debris beds for the Series I tests were formed at a constant screen approach velocity of 0.1 ft/sec). The test conditions are summarized in Table H.5.1 and preliminary data are listed in Table H.5.2.

All data herein are preliminary and were obtained from manual recordings taken from visual observation of the DAS screen readouts. In Table H.5.5, zero and cold-leg/hot-leg temperature corrections for the delta pressure transducers and associated manifold have been applied to the preliminary head loss data values. These corrections may not result in a change of the preliminary head loss data. Testing was conducted in accordance with the specifications, plans, and limitations contained in correspondence *051108 NRC weekly notes.doc*. The test section ID is 0.154 m (6.06 in.).

The debris beds formed typically had a raised annular rim of material against the wall of the test section that was thicker than the body of the debris bed. During testing, the height of the rim is a direct measurement taken at the wall of the test section. The height of the body of the debris bed was estimated by visually observing and measuring the elevation above the screen at which a difference in backlighting was observed showing through the rim. These measurements are referred to as manual. In situ debris bed height measurements were also taken using optical triangulation.

Manual debris bed height measurements are reported in Table H.5.3 and Figure H.5.1. Figure H.5.2 compares measurements made in several tests. The top of the screen assembly support ring was used as the reference datum to obtain the debris bed height measurements under flow conditions. The actual top of the screen is approximately 0.06 to 0.08 in. below this datum; therefore, 0.06 in has been added to the reported measurements.

Table H.5.1. Test Conditions

Quick-Look Report date	2/3/06
Date of test	1/25/06
Associated test case(s)	LANL 1a; PNNL large-scale 051108_NO_3067_L1; PNNL benchtop 050803_NO_1363_1, 050815_NO_1363_1
Test number and data file reference	060125_NO_3067_L1
Target screen debris loading (g/m^2)	1681.4
Initial NUKON mass introduced (g)	30.67
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	0.0
CalSil R4 target	N/A
Initial bed formation screen approach velocity (ft/sec)	0.20
Final bed formation screen approach velocity (ft/sec)	0.17
Bed formation time (min)	70
Calculated number of representative circulations during debris bed formation (from estimated 5-minute circulation time)	14
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	32.05[(a)]

(a) Loop flushing was limited due to time constraints of test. Also, debris from current loop construction is apparent on/in debris bed. Issues will be resolved for subsequent tests.

Post-retrieval debris bed height measurements taken upon bed retrieval are provided in Table H.5.3. While the rim is apparently 0.22 in. less for this test than in 051108_NO-3067_L1, the body height is essentially equivalent, with a 0.01 in. difference.

The determination of the debris bed height from the optical triangulation technique is made by post-test analysis of digital photographs taken of the debris bed during the test (Figures H.5.3–H.5.5. A series of evenly spaced parallel lines are projected onto debris bed surface. Digital pictures are then taken at a known fixed angle and the images compared with those taken with the same line projection on known calibrated surfaces.

The debris bed height determined from the optical triangulation debris bed height measurements are reported in Table H.5.5. These data represent the points analyzed; additional points for evaluation are available. The picture/test condition denotes the test date (060125), the loop and test number in that loop on that date (L for PNNL large scale and 1 for 1st test), screen approach velocity (018 for 0.18 ft/sec, 098 for 0.98 ft/sec, etc.), picture number from camera, and test phase (BF for bed formation, RU1 for first rampup, RU4 for fourth rampup, and RD4 for ramp down 4). The apparent effect of flow condition as indicated by the data in Table H.5.5 suggests that comparison to the post-test measurements in Table H.5.4 is not meaningful. Contour plots of the debris bed height are provided at the end of the photograph section of this report (Figures H.5.6 through H.5.9).

Table H.5.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim (in.)	Estimated Body[a] (in.)	
Rampup 1	0.17	43[b]	0.57	0.45	22
	0.2	61[b]	0.53	0.41	22
	0.2	63	0.53	0.41	22
	0.4	143	0.49	0.33	22
	0.57	219	0.47	0.30	22
	0.7	284	0.45	-	22
	0.9	360	0.45	-	23
Ramp down 1	0.98	404	0.41	-	23
	0.88	352	0.41	-	25
	0.7	265	0.41	-	25
	0.56	204	0.43	-	25
	0.4	133	0.45	-	25
Rampup 2	0.2	57	0.45	-	25
Ramp down 2	0.97	423	0.41	-	25
Rampup 3	0.2	60	0.45	-	25
Ramp down 3	0.96	422	0.37	-	25
Rampup 4	0.19	58	0.45	-	25
	0.41	142	0.43	-	25
	0.7	284	0.43	-	26
Ramp down 4	0.97	438	0.37	-	26
	0.69	288	0.39	-	26
	0.41	147	0.43	-	26
	0.2	61	0.45	-	26
	0.1	27	0.45	-	26
Rampup 5	0.05	12	0.49	-	26
	0.1	29	0.45	-	26
	0.19	62	0.45	-	26

(a) The estimated body height of the debris bed was taken by visually observing and recording the elevation of the screen at which a different amount of backlight showed through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.
(b) Prior to increase of loop static pressure (~2.5 atm).

Table H.5.3. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.50	0.34	6.06	5.71

Table H.5.4. In Situ Debris Bed Measurements

Optical Triangulation Debris Bed Measurements						
Picture/Test Condition	Height (in.)			Diameter (in)	Volume (in.^{3})	
	Rim	Body Center	Average Body	Body	Body	Total Debris Bed
060125_L1_018_1_BF	0.635	0.307	0.292	5.31	6.46	10.35
060125_L1_098_2_RU1	0.325	0.055	0.053	5.59	1.29	2.49
060125_L1_096_10_RU4	0.281	0.04	0.049	5.63	1.23	2.18
060125_L1_005_13_RD4	0.31	0.129	0.124	5.68	3.13	4.04

Table H.5.5. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.17	43	22	22
	0.2	61	22	22
	0.2	63	22	22
	0.4	143	22	22
	0.57	219	22	22
	0.7	284	22	22
	0.9	360	23	22
Ramp down 1	0.98	404	23	22
	0.88	352	25	22
	0.7	265	25	22
	0.56	204	25	22
	0.4	133	25	22
Rampup 2	0.2	57	25	22
Ramp down 2	0.97	423	25	22
Rampup 3	0.2	60	25	22
Ramp down 3	0.96	422	25	22
Rampup 4	0.19	58	25	22
	0.41	142	25	22
	0.7	284	26	22
Ramp down 4	0.97	438	26	22
	0.69	288	26	22
	0.41	147	26	22
	0.2	61	26	22
	0.1	27	26	22

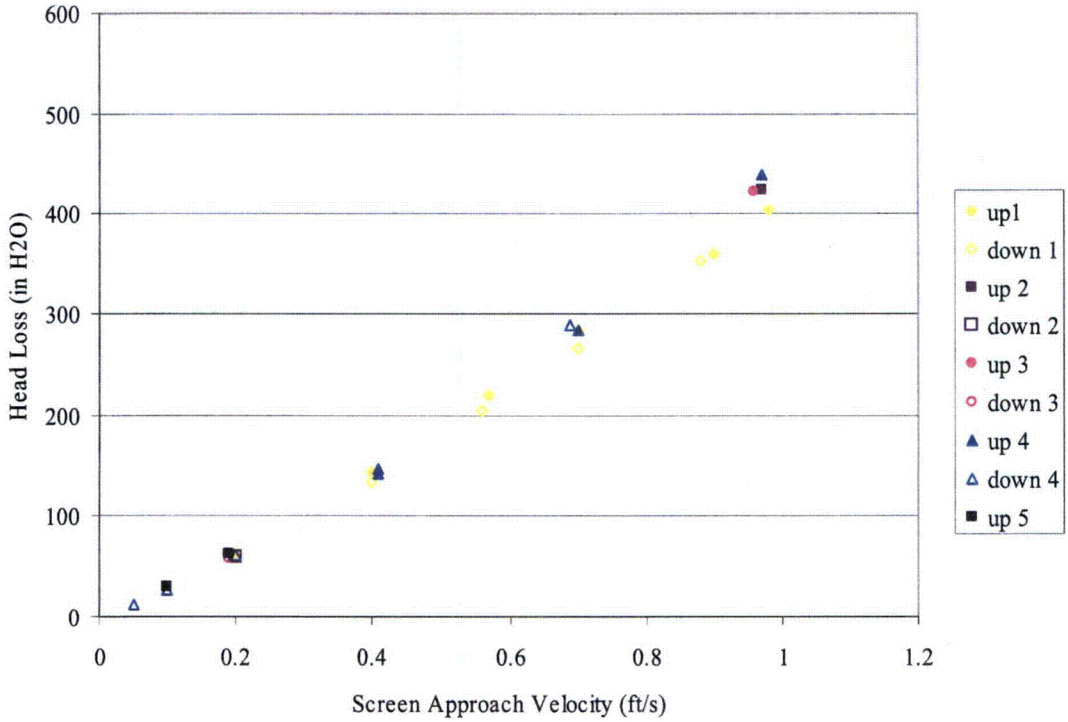


Figure H.5.1. Preliminary PNNL Data; 060125_NO_3067_L1

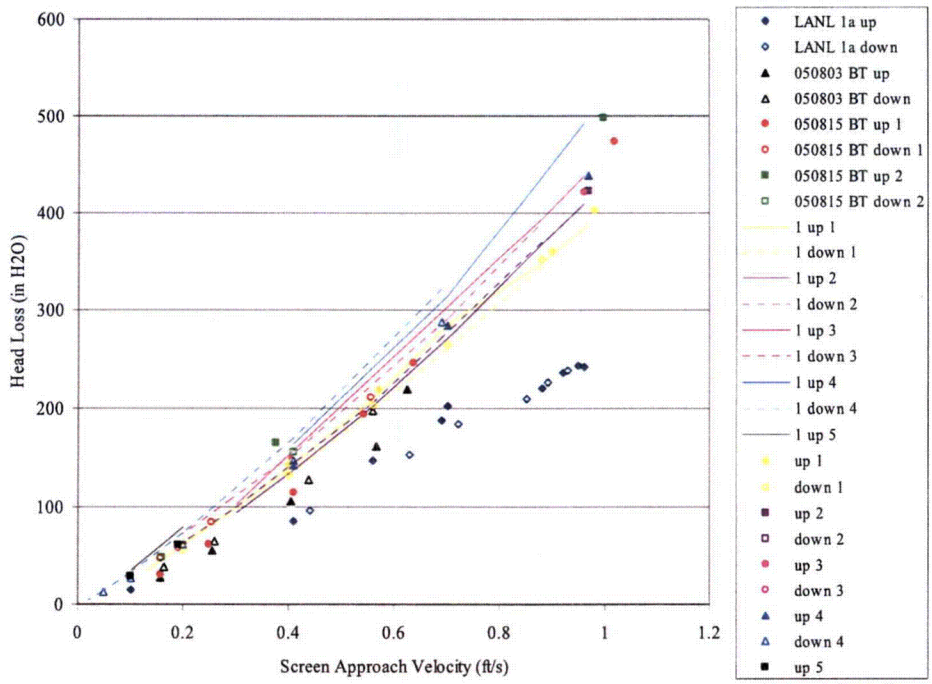


Figure H.5.2. Comparison of Preliminary PNNL Data from Test 060125_NO_3067L1 (denoted as "up" and "down") with Previous Results (BT denotes PNNL benchtop, 1 denotes Test 051108_NO_3067_L1)

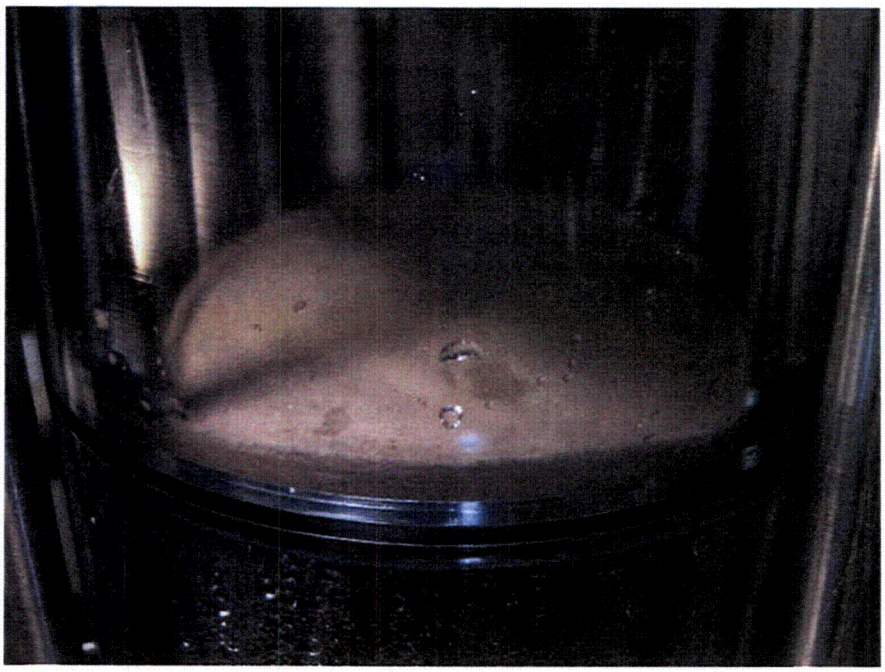


Figure H.5.3. 060125_NO_3067_L1 Debris Bed in Large Scale Loop After Draining

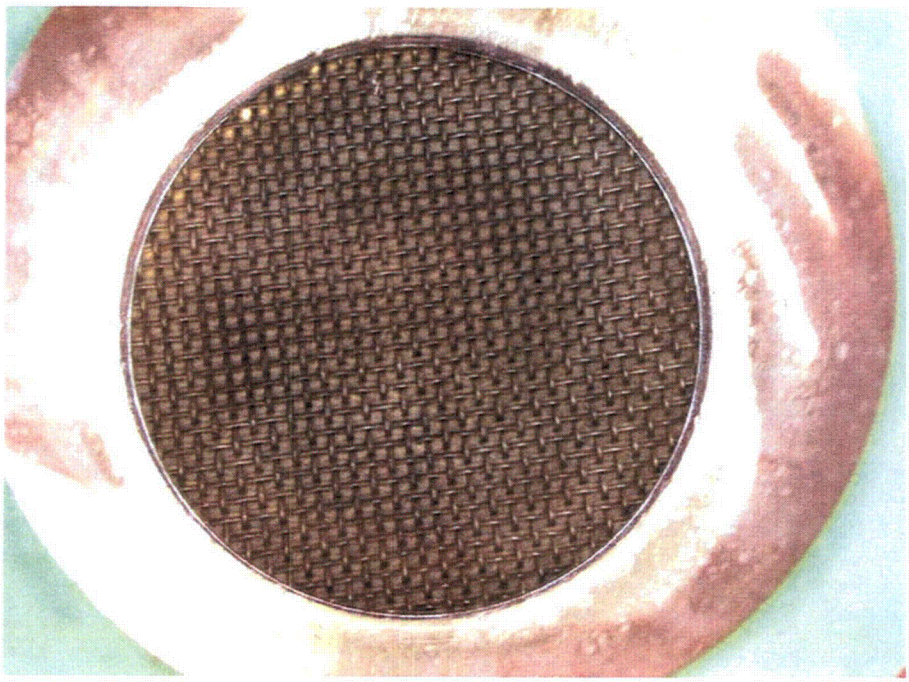


Figure H.5.4. 060125_NO_3067_L1 Debris Bed in Test Section After Retrieval, Bottom View

Figure H.5.5. 060125_NO_3067_L1 Debris Bed After Retrieval from Test Section

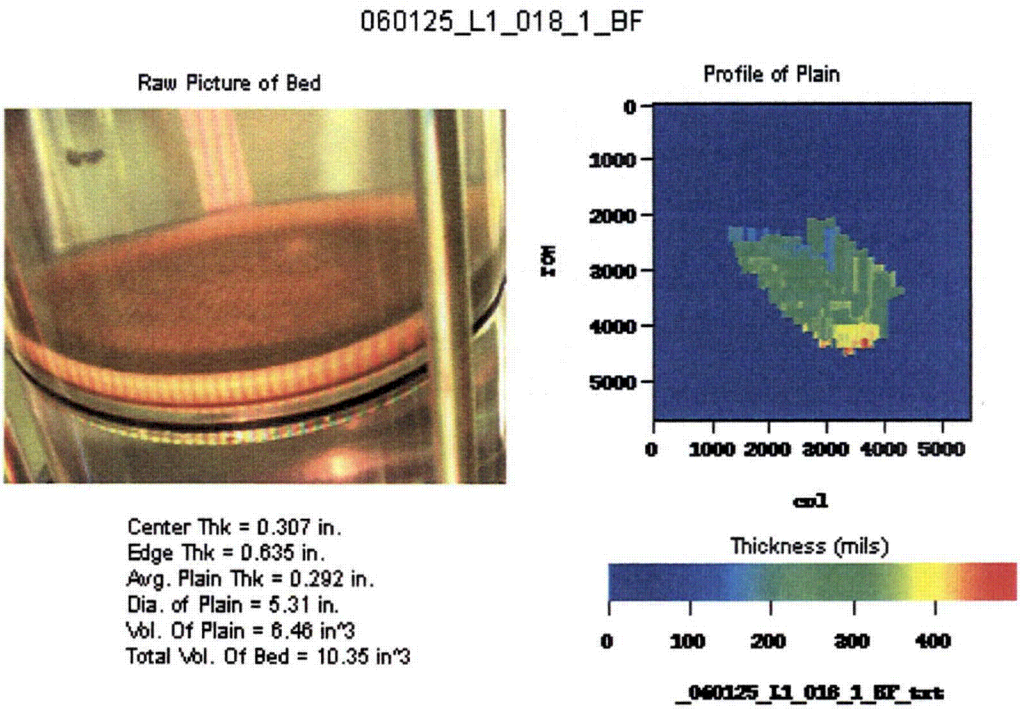
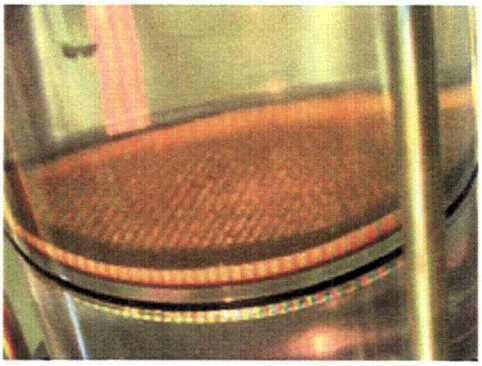


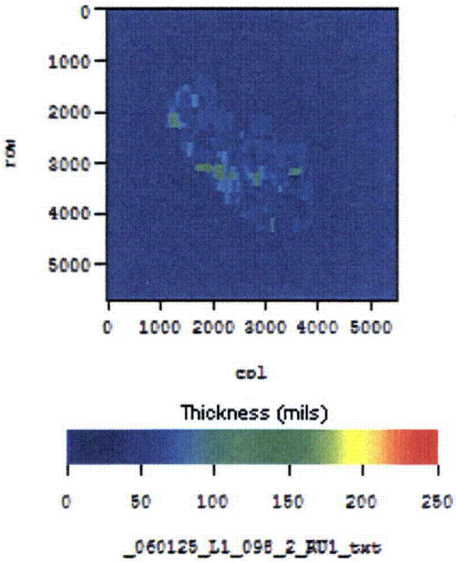
Figure H.5.6. Contour Plots of Debris Bed Height

060125_L1_098_2_RU1

Raw Picture of Bed



Profile of Plain

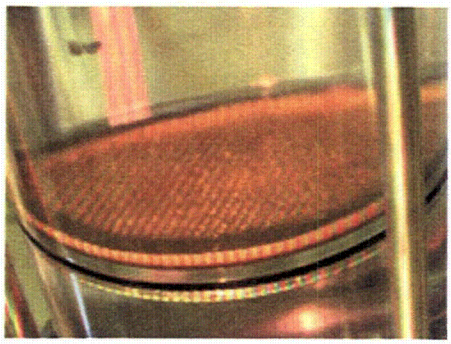


Center Thk = 0.055 in.
Edge Thk = 0.325 in.
Avg. Plain Thk = 0.053 in.
Dia. of Plain = 5.59 in.
Vol. Of Plain = 1.29 in^3
Total Vol. Of Bed = 2.49 in^3

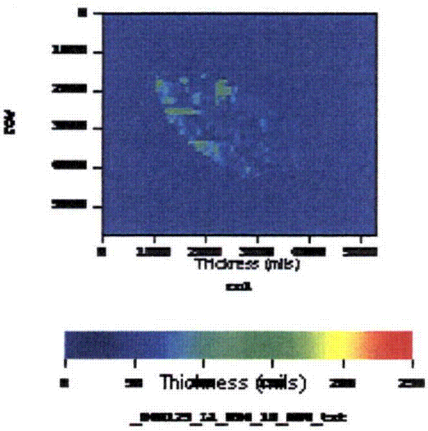
Figure H.5.7. Contour Plots of Debris Bed Height

060125_L1_096_10_RU4

Raw Picture of Bed



Profile of Plain



Center Thk = 0.040 in.
Edge Thk = 0.281 in.
Avg. Plain Thk = 0.049 in.
Dia. of Plain = 5.63 in.
Vol. Of Plain = 1.23 in^3
Total Vol. Of Bed = 2.18 in^3

Figure H.5.8. Contour Plots of Debris Bed Height

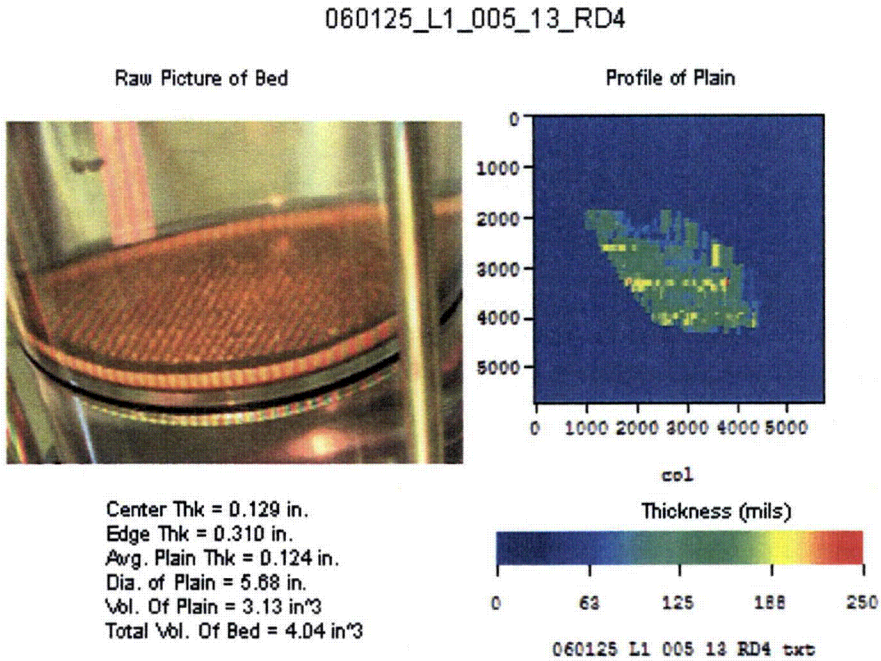


Figure H.5.9. Contour Plots of Debris Bed Height

H.6 Quick-Look Report for PNNL Tests 060731_NO_2703_LP1 and 060731_NO_2703_LP2, Test Condition Series at Priority 1, 54°C, Preliminary PNNL Head Loss Test Data

All data herein are preliminary. Test conditions are reported in Table H.6.1, and preliminary test data are reported in Tables H.6.2 and H.6.3. The data were obtained from manual recordings taken from visual observation of the DAS screen readouts. Head loss measurements were obtained from visual observation of DAS screen using the 60-second-averaged meter readouts. In Tables H.6.4 and H.6.5, zero and cold-leg/hot-leg temperature corrections for the delta pressure transducers and associated manifold have been applied to the preliminary head loss data values. These corrections may not result in a change of the preliminary head loss data. The value reported is from the DP meter with the most appropriate span for the given range of head loss readings. The head loss data presented have not had cold-leg/hot-leg temperature corrections applied.[a] Testing was conducted in accordance with the provided test plan and communication with the client.[b] The test section inside diameter is 0.154 m (6.06 in.).

The debris bed formed had a raised rim against the wall of the test section that was thicker than the body of the debris bed. During testing, the height of the rim is a direct measurement taken at the wall of the test section. The height of the body of the debris bed was estimated by visually observing and measuring the elevation above the screen at which a difference in the backlighting, which shows through the rim, was observed. These manual measurements of the debris-bed body are not always obtainable because

[a] Temperature differences attainable between the DP "legs" during testing can affect the head loss measurement. Data uncertainties will be elucidated in the final report.

[b] CW Enderlin to WJ Krotiuk. April 4, 2006. *Plans for Conducting Debris-Bed Head Loss Tests in the PNNL Large-Scale Test Loop During April 2006.* 060404 April test program memo.doc.

Table H.6.1. Test Conditions

Quick-Look Report Date	9/5/06
Date of test	7/31/06
Associated test case(s)	Series 2 Priority 1
Test number(s) and data file reference(s)	060731_NO_2703_LP1 060731_NO_2703_LP2
Sump screen material installed in test section	Perforated plate. 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	1,450
Initial NUKON mass introduced (g)	27.03
NUKON R4 target	10 - 12
Initial CalSil mass introduced (g)	0.0
CalSil R4 target	N/A
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	62
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	7
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	23.3

Table H.6.2. Preliminary Data, LP1

Test Phase	Velocity (ft/sec)	Head Loss[a] (in H_2O)	Manual Debris Bed Height Measurement[b]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Bed Formation	0.10	17[c]	0.46	0.22	55
Rampup 1	0.10	18	0.44	0.22	55
Rampup 1 (pre filtering)	0.20	43	0.36	0.22	55
Rampup 1 (post-filtering)	0.20	51	0.30	0.22	53
Ramp down 1	0.10	23	0.30	0.22	54
Ramp down 1	0.05	11	0.28	0.22	55
Ramp down 1	0.02	4	0.30	0.22	54
Rampup 2	0.10	24	0.30	0.22	54
Rampup 2	0.20	52	0.30	0.22	55
Ramp down 2	0.10	24	0.30	0.22	54
Ramp down 2	0.02	4	0.30	0.22	54
Rampup 3	0.10	25	0.30	0.22	55
Rampup 3	0.20	47	0.30	0.22	54
Ramp down 3	0.10	25	0.30	0.22	54
Ramp down 3	0.02	4	0.30	0.22	54
Rampup 4	0.10	25	0.30	0.22	55

(a) DP meters online during testing: 0 -5, 0 - 30, 0 – 150, and 0 – 750 in H2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.

(b) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation off the screen at which there was a difference in the amount of back-light which shown through the rim. Blank (-) entries indicate that no measurement was taken as a difference in the back-lighting was not observed.

(c) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).

Table H.6.3. Preliminary Data, LP2

Test Phase	Velocity (ft/sec)	Head Loss[a] (in H_2O)	Manual Debris Bed Height Measurement[b]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Rampup 1	0.10	47	0.30	0.22	28
Rampup 1	0.20	112	0.30	0.22	27
Ramp down 1	0.10	51	0.30	0.22	27
Ramp down 1	0.02	6	0.30	0.22	27
Rampup 2	0.10	49	0.30	0.22	27

(a) DP meters online during testing: 0–5, 0–30, 0–150, and 0–750 in. H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.

(b) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation off the screen at which there was a difference in the amount of backlight showing through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.

Table H.6.4. Corrected Data, LP1

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	16	55	26
Rampup 1	0.10	17	55	26
Rampup 1 (prefiltering)	0.20	42	55	27
Rampup 1 (post-filtering)	0.20	50	53	27
Ramp down 1	0.10	22	54	28
Ramp down 1	0.05	10	55	28
Ramp down 1	0.02	3	54	28
Rampup 2	0.10	23	54	28
Rampup 2	0.20	51	55	28
Ramp down 2	0.10	23	54	29
Ramp down 2	0.02	3	54	29
Rampup 3	0.10	24	55	29
Rampup 3	0.20	46	54	29
Ramp down 3	0.10	24	54	21
Ramp down 3	0.02	2	54	21
Rampup 4	0.10	24	55	21

Table H.6.5. Corrected Data, LP2

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.10	47	28	20
Rampup 1	0.20	112	27	20
Ramp down 1	0.10	51	27	20
Ramp down 1	0.02	6	27	20
Rampup 2	0.10	49	27	20

a difference in backlighting is not always observed. In situ debris bed height measurements were also taken using optical triangulation, as described below.

Manual debris bed height measurements are reported in Tables H.6.6 and H.6.7. The top of the perforated plate assembly support ring was used as the reference datum to obtain the debris bed height measurements under flow conditions. The actual top of the perforated plate is approximately 0.0625 in. below this datum. Therefore, 0.0625 in. has been added to the reported measurements.

Post-retrieval debris bed height measurements taken upon bed retrieval are provided in Table H.6.6. The determination of the debris bed height from the optical triangulation technique is made by post-test analysis of digital photographs taken of the debris bed during the test. A series of evenly spaced parallel lines is projected onto debris bed surface. Digital pictures are then taken at a known fixed angle and these images are compared with those taken with the same line projection on known calibrated surfaces (Figures H.6.1–H.6.2). Photographs of the debris beds are provided in Figures H.6.3–H.6.5.

The debris bed height determined from the optical triangulation debris bed height measurements are reported in Table H.6.7. These data represent the points currently analyzed; additional points for evaluation are available. The Picture/Test Condition denotes the test date, the loop, perforated plate and test number in that loop on that date, screen approach velocity, picture number from camera, and test phase with respect to the velocity matrix.

Table H.6.6. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	**Body Height (in.)**	**Total Bed Diameter (in.)**	**Body Diameter (in.)**
0.54	0.40	6.065	N/A

Table H.6.7. In Situ Debris Bed Measurements

Optical Triangulation Debris Bed Measurements						
	Height (in.)			Diameter (in.)	Volume (in.^{3})	
Picture/Test Condition	**Rim**	**Body Center**	**Average Body**	**Body**	**Body**	**Total Debris Bed**
060731_LP1_0.1_30_RU1	0.64	0.50	0.48	5.24	10.37	14.45
060731_LP1_0.2_32_RU1	0.49	0.31	0.29	5.11	5.95	9.22
060731_LP1_0.2_41_RU3	0.50	0.31	0.29	5.09	5.91	9.27
060731_LP1_0.02_43_RD3	0.50	0.40	0.38	5.30	8.39	11.39
060731_LP1_0.1_44_RU4	0.50	0.33	0.31	5.14	6.42	9.73
060731_LP2_0.2_46_RU1	0.49	0.23	0.21	5.08	4.26	7.27
060731_LP2_0.1_49_RU2	0.48	0.28	0.26	5.18	5.47	8.37

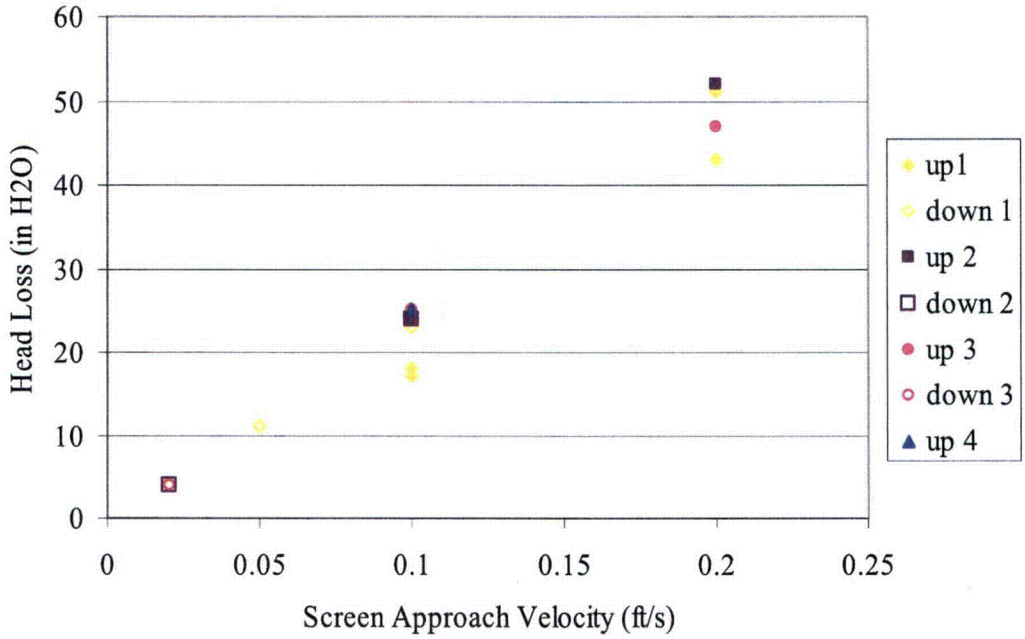


Figure H.6.1. Preliminary PNNL Data, LP1

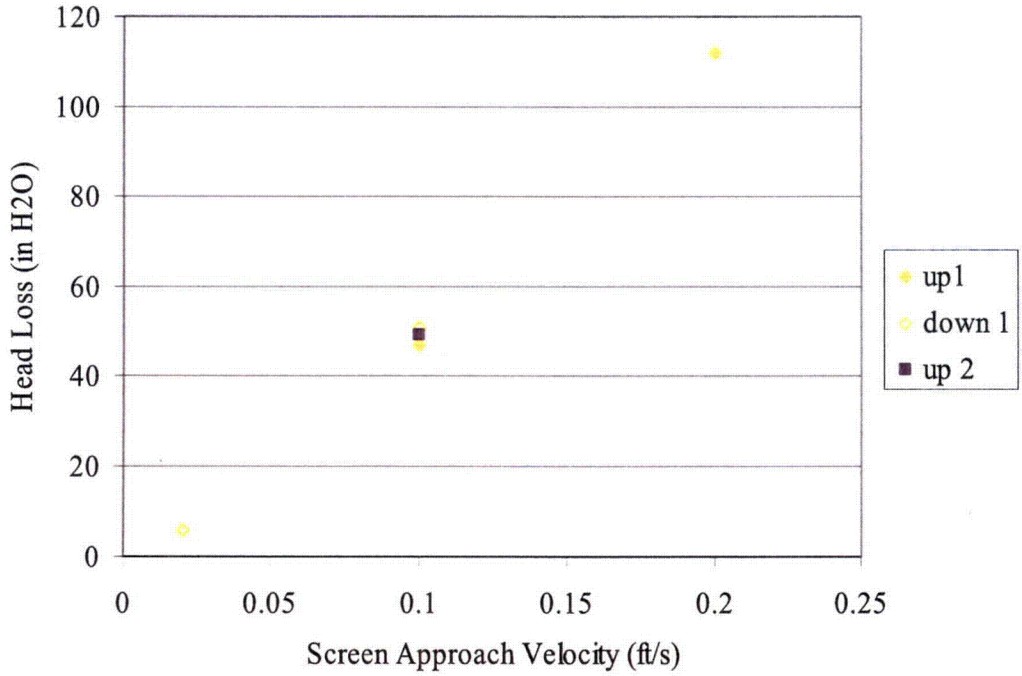


Figure H.6.2. Preliminary PNNL Data, LP2

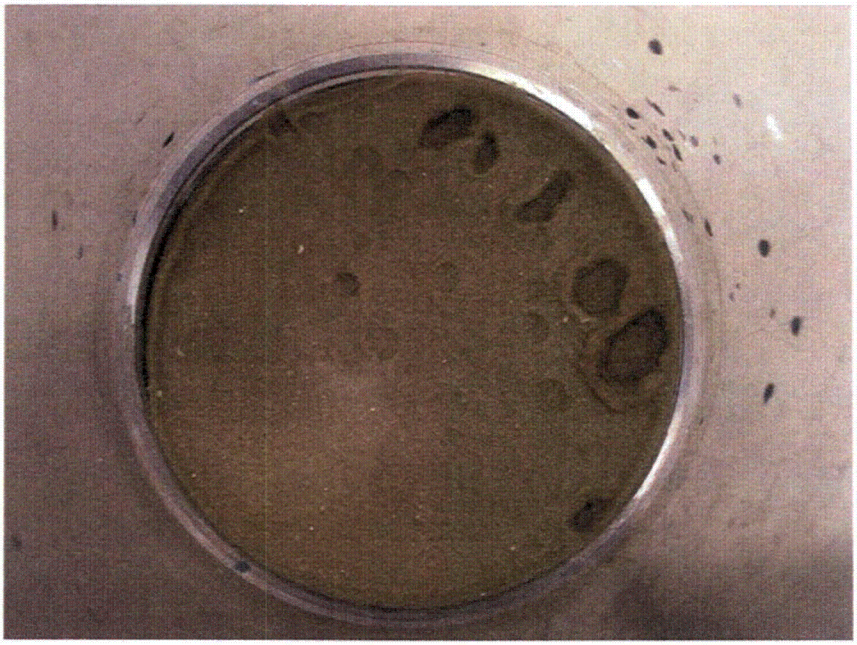


Figure H.6.3. Debris Bed in Test Section After Retrieval, Top View. Disturbed post-test.

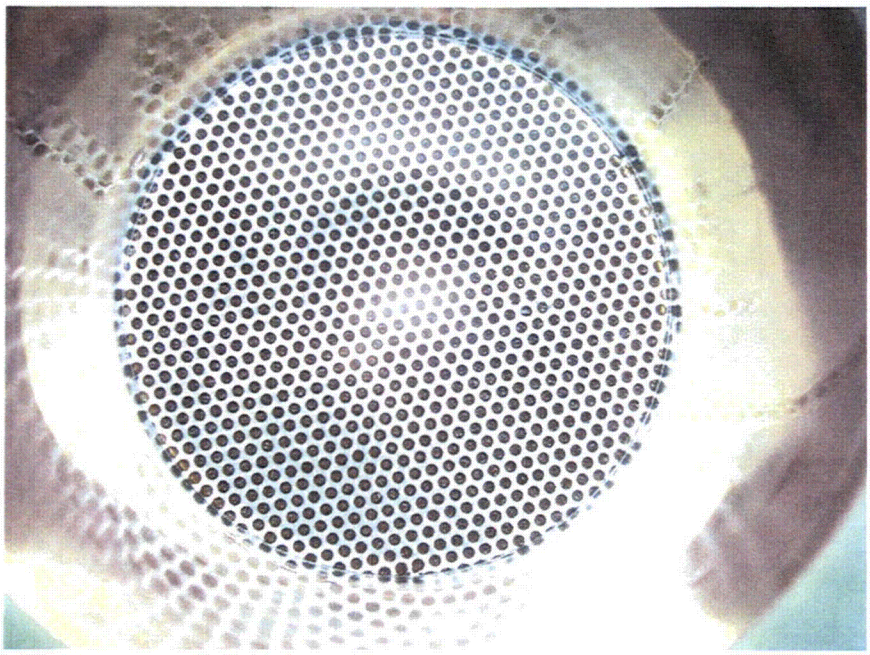


Figure H.6.4. Debris Bed in Test Section After Retrieval, Bottom View.

Figure H.6.5. Debris Bed After Retrieval from Test Section, Disturbed Post-Test

H.7 Quick-Look Report for PNNL Tests 060802_NO_2703_LP1 and 060802_NO_2703_LP2, Test Condition Series at Priority 1, 82°C Preliminary PNNL Head Loss Test Data

All data herein are preliminary. Test conditions are reported in Table H.7.1 and preliminary test data in Tables H.7.2 and H.7.3. The data were obtained from manual recordings taken from visual observation of the DAS screen readouts. Head loss measurements were obtained from visual observation of DAS screen using the 60 sec averaged meter readouts. In Tables H.7.4 and H.7.5, zero and cold-leg/hot-leg temperature corrections for the delta pressure transducers and associated manifold have been applied to the preliminary head loss data values. These corrections may not result in a change of the preliminary head loss data. The value reported is from the DP meter with the most appropriate span for the given range of head loss readings. The head loss data have not had cold-leg/hot-leg temperature corrections applied. Testing was conducted in accordance with the provided test plan and communication with the client. The test section inside diameter is 0.154 m (6.06 in.).

The debris bed formed had a raised annular rim of material against the wall of the test section that was thicker than the body of the debris bed. During testing, the height of the rim is a direct measurement taken at the wall of the test section. The height of the body of the debris bed was estimated by visually observing and measuring the elevation above the screen at which a difference in the backlighting showing through the rim was observed. These manual measurements of the debris-bed body are not always

obtainable because a difference in backlighting is not always observed. In situ debris bed height measurements were also taken using optical triangulation as described below.

Manual debris bed height measurements are reported in Tables H.7.6 and H.7.7. The top of the perforated plate assembly support ring was used as the reference datum to obtain the debris bed height measurements under flow conditions. The actual top of the perforated plate is approximately 0.0625 in. below this datum. Therefore, 0.0625 in. has been added to the reported measurements.

Post-retrieval debris bed height measurements taken upon bed retrieval are provided in Table H.7.6. The determination of the debris bed height from the optical triangulation technique is made by post-test analysis of digital photographs taken of the debris bed during the test (see Figures H.7.1–H.7.2). A series of evenly spaced parallel lines are projected onto debris bed surface. Digital pictures are then taken at a known fixed angle and these images are compared to those taken with the same line projection on known calibrated surfaces.

The debris bed height determined from the optical triangulation debris bed height measurements are reported in Table H.7.7. This data represents those points currently analyzed; additional points for evaluation are available. The Picture/Test Condition denotes the test date, the loop, perforated plate and test number in that loop on that date, screen approach velocity, picture number from camera, and test phase with respect to the velocity matrix (see Figures H.7.3 through H.7.5).

Table H.7.1. Test Conditions

Quick-Look Report Date	9/5/06
Date of test	8/2/06
Associated test case(s)	Series 2 Priority 1
Test number(s) and data file reference(s)	060802_NO_2703_LP1 060802_NO_2703_LP2
Sump screen material installed in test section	Perforated plate. 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	1,450
Initial NUKON mass introduced (g)	27.03
NUKON R4 target	10 - 12
Initial CalSil mass introduced (g)	0.0
CalSil R4 target	N/A
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	60
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	7
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	22.19

Table H.7.2. Preliminary Data, LP1

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement[b]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Bed Formation	0.10	6[c]	0.59	0.46	81
Rampup 1	0.10	7	0.69	0.53	82
Rampup 1 (prefiltering)	0.20	14	0.65	0.50	82
Rampup 1 (post-filtering)	0.20	17	0.65	0.50	80
Ramp down 1	0.10	9	0.63	0.50	81
Ramp down 1	0.05	5	0.61	0.50	80
Ramp down 1	0.02	4	0.61	0.57	79
Rampup 2	0.10	9	0.61	0.53	83
Rampup 2	0.20	17	0.59	0.53	82
Ramp down 2	0.10	9	0.59	0.53	82
Ramp down 2	0.02	4	0.59	0.53	81
Rampup 3	0.10	9	0.59	0.53	83
Rampup 3	0.20	18	0.59	0.53	82
Ramp down 3	0.10	9	0.59	0.53	82
Ramp down 3	0.02	4	0.59	0.53	81
Rampup 4	0.10	9	0.59	0.53	83

(a) DP meters online during testing: 0 -5, 0 - 30, 0 – 150, and 0 – 750 in H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation off the screen at which there was a difference in the amount of back-light which shown through the rim. Blank (-) entries indicate that no measurement was taken as a difference in the back-lighting was not observed.
(c) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).

Table H.7.3. Preliminary Data, LP2

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement[b]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Rampup 1	0.10	13	0.57	0.50	54
Rampup 1	0.20	29	0.57	0.50	55
Ramp down 1	0.10	14	0.57	0.50	55
Ramp down 1	0.02	3	0.57	0.50	57
Rampup 2	0.10	14	0.57	0.50	55

(a) DP meters online during testing: 0 -5, 0 - 30, 0 – 150, and 0 – 750 in H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.
(b) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation off the screen at which there was a difference in the amount of back-light which shown through the rim. Blank (-) entries indicate that no measurement was taken as a difference in the back-lighting was not observed.

Table H.7.4. Corrected Data, LP1

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	3	81	22
Rampup 1	0.10	4	82	22
Rampup 1 (prefiltering)	0.20	11	82	22
Rampup 1 (post-filtering)	0.20	14	80	23
Ramp down 1	0.10	6	81	23
Ramp down 1	0.05	2	80	23
Ramp down 1	0.02	1	79	23
Rampup 2	0.10	6	83	23
Rampup 2	0.20	14	82	23
Ramp down 2	0.10	6	82	23
Ramp down 2	0.02	1	81	23
Rampup 3	0.10	6	83	23
Rampup 3	0.20	15	82	23
Ramp down 3	0.10	6	82	23
Ramp down 3	0.02	1	81	23
Rampup 4	0.10	6	83	23

Table H.7.5. Corrected Data, LP2

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.10	12	54	23
Rampup 1	0.20	28	55	23
Ramp down 1	0.10	12	55	22
Ramp down 1	0.02	1	57	22
Rampup 2	0.10	12	55	22

Table H.7.6. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.45	0.30	6.065	N/A

Table H.7.7. In Situ Debris Bed Measurements

Optical Triangulation Debris Bed Measurements						
	Height (in.)			Diameter (in.)	Volume (in.^{3})	
Picture/Test Condition	Rim	Body Center	Average Body	Body	Body	Total Debris Bed
060802_LP1_0.1_55_RU1	0.71	0.63	0.61	5.50	14.50	17.88
060802_LP1_0.2_57_RU1	0.65	0.52	0.50	5.52	11.95	14.82
060802_LP1_0.2_66_RU3	0.57	0.46	0.44	5.38	10.02	13.11
060802_LP1_0.1_67_RD3	0.57	0.46	0.44	5.49	10.42	13.05
060802_LP1_0.02_68_RD3	0.58	0.56	0.54	5.70	13.80	15.67
060802_LP2_0.2_71_RU1	0.50	0.32	0.30	5.24	6.46	9.40
060802_LP2_0.1_74_RU2	0.50	0.33	0.31	5.18	6.53	9.70

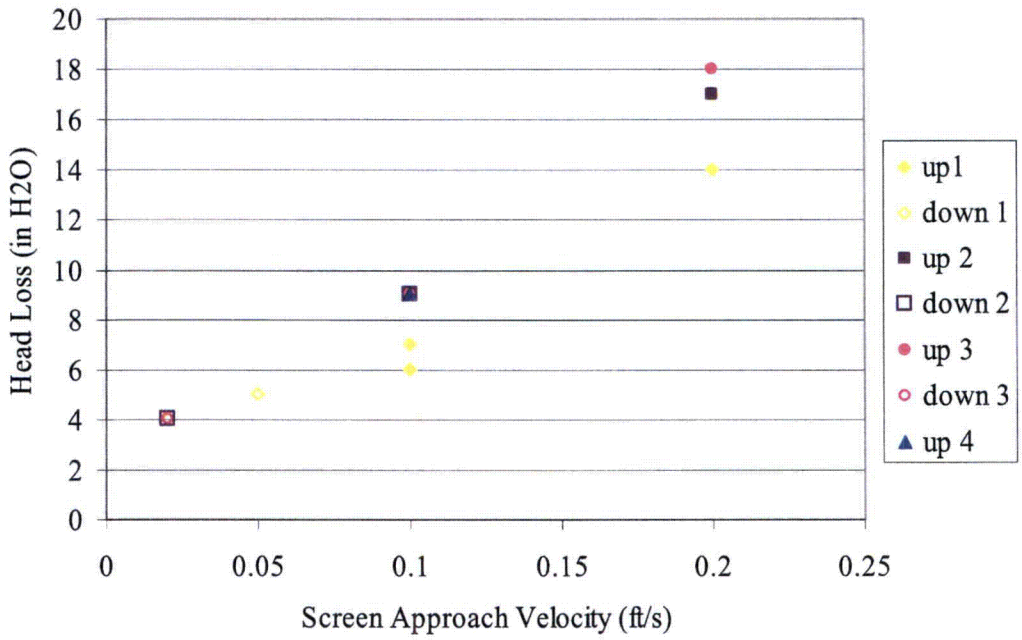


Figure H.7.1. Preliminary PNNL Data, LP1

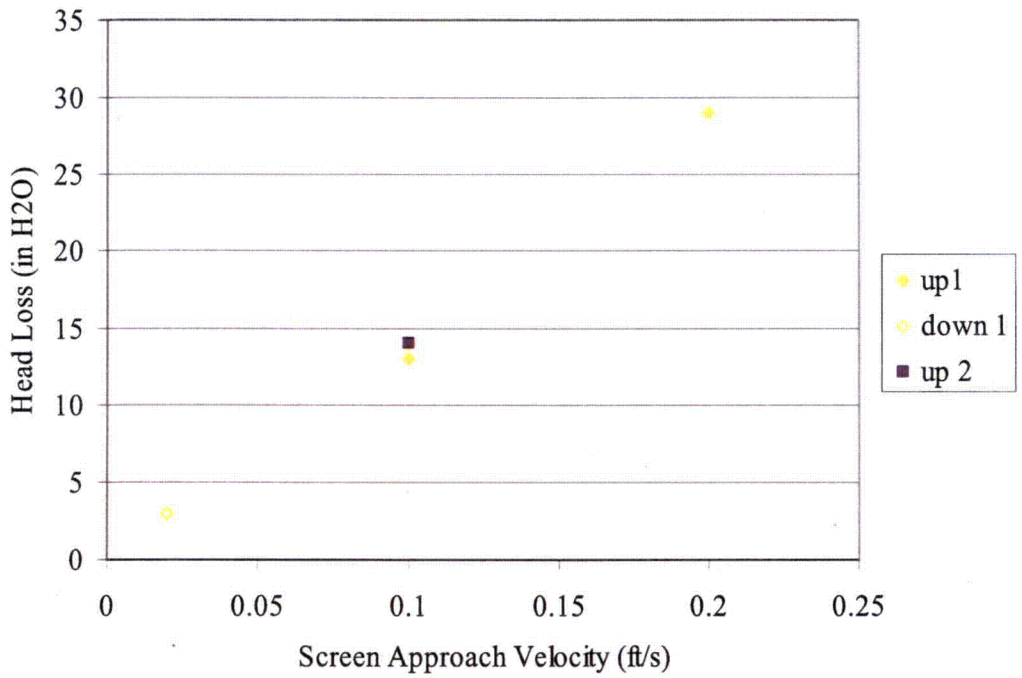


Figure H.7.2. Preliminary PNNL Data, LP2

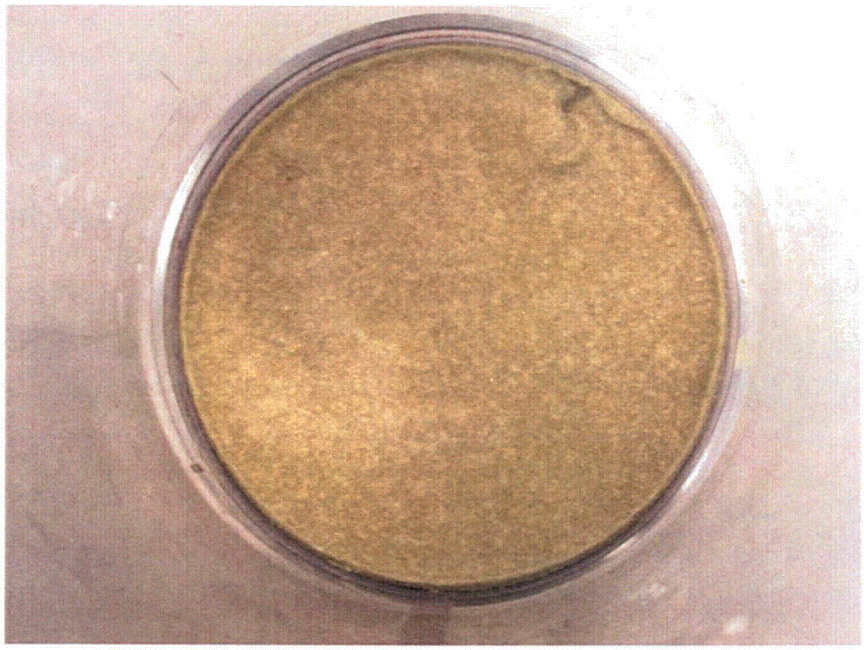


Figure H.7.3. Debris Bed in Test Section After Retrieval, Top View. Disturbed post-test.

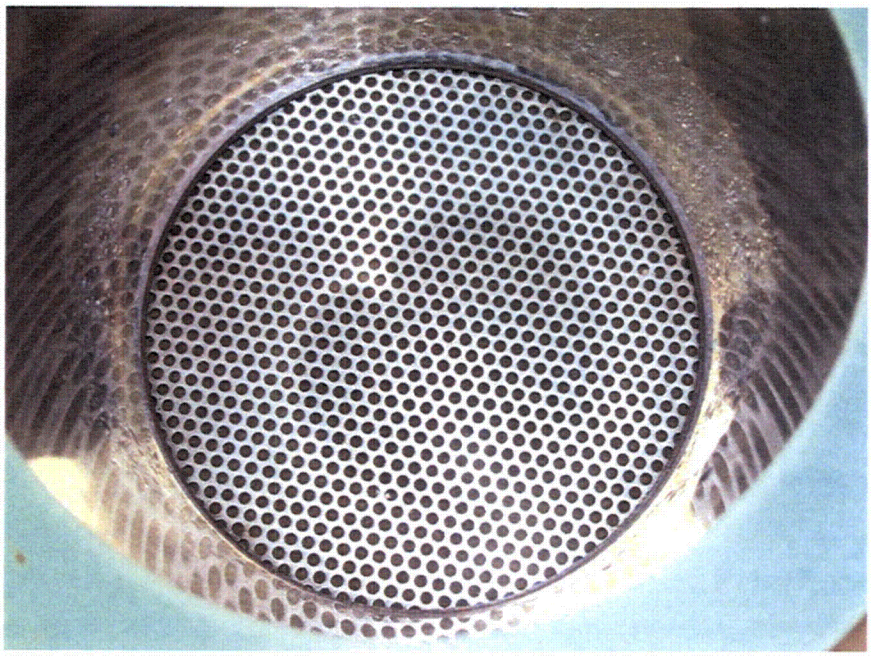


Figure H.7.4. Debris Bed in Test Section After Retrieval, Bottom View

Figure H.7.5. Debris Bed After Retrieval from Test Section. Disturbed post-test.

Appendix I – CalSil-Only Quick-Looks

Appendix I – CalSil-Only Quick-Looks

I.1 Quick-Look Report for PNNL Benchtop Test 060406_CO_1176_BP1, Test Condition Series II Priority 2

This Quick-Look report conveys preliminary data from the PNNL Benchtop Test Loop test condition Series II Priority 2. This test was performed to evaluate the potential for forming a debris bed on a perforated plate with the maximum CalSil-only debris loading for the Series II test matrix, priorities 1–5. All data contained herein are preliminary and were obtained from manual recordings taken from visual observation of the data acquisition system (DAS) screen readouts. Testing was conducted in accordance with *060404 April test program memo.doc* as applicable in the PNNL benchtop test loop and under the flow conditions described. The benchtop loop test section inside diameter is 0.1016 m (4 in.).

The bed formation was conducted at a screen approach velocity of 0.1 ft/sec for 20 minutes. Upon completion, it was determined that an incomplete debris bed had formed (see *060404 April test program memo.doc*). Thus, to possibly mobilize potentially settled CalSil debris, transport it to the screen, and potentially form a complete debris bed with the possible additional debris mass in the flow, the screen approach velocity was increased to 0.2 ft/sec for 20 additional minutes. Additional material accumulated on the debris bed based on visual observations; however, the debris bed was judged to be incomplete. Test observations are listed in Table I.1.1. Preliminary data are listed in Table I.1.2.

Table I.1.1. Test Conditions

Quick-look report date	4/21/06
Date of test	4/6/06
Associated test case(s)	Series II Priority 2
Test number and data file reference	060406_CO_1176_BP1
Sump screen material installed in test section	Perforated plate; 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	1450
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	11.76
CalSil R4 target	< 1.55
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	20
Calculated number of representative circulations during debris bed formation (from estimated 1.5-minute circulation time)	13
Target static pressure increase (psig)	N/A, PNNL Benchtop
Ports used for debris bed head loss measurements	N/A, PNNL Benchtop
Dry retrieved debris bed mass (g)	0.64

Table I.1.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)
Bed Formation	0.10	0.0
Rampup 1	0.20	0.1

At 0.1 ft/sec, CalSil debris was visually observed to be deposited on the debris screen after 1–4 cycles. Two definite holes (referred to as channels) were observed in the middle of the debris bed, and an opening on the edge of the debris screen was observed as well. There was no head loss indicated by the 0 to 1000 in H_2O delta-P transmitter used in the benchtop loop. The test section became mildly cloudy, rendering it difficult to observe any definite details. After 20 minutes, the holes in the debris bed and openings in the perforated plate were still visible.

At 0.2 ft/sec, one circulation of the flow loop seemed, based on visual observation, to fill up the holes/openings on the debris bed. However, the complete debris bed was not sustained, as described below, and no appreciable head-loss was indicated by the delta-P transmitter. The test section then became very murky, making it extremely difficult to observe the debris bed. The presence of similar amounts (as judged by visual observation) of CalSil debris both above and below the plate may indicate the CalSil was either passing uninhibited through the perforated plate or possibly being deposited on the plate but also being lost from the debris bed at a similar rate. Because of the very murky test section, it was impossible to see whether the holes/openings in the perforated plate were re-exposed.

Although the head loss did slightly increase at the elevated flow rate, it is not believed, based on comparison to completely formed minimum debris loading NUKON-only debris bed head loss performance (refer to *060309 Debris Preparation DRAFT.doc* and *051110 Quick-Look 6h.doc*), that a complete debris bed (as defined in *060404 April test program memo.doc*) was formed.

For debris bed removal, the standard procedure was used. Because there was little to no head loss, the test section water may have been removed too fast (compared with completely formed minimum loading NUKON-only debris beds), and a potentially significant portion of the retained CalSil debris was observed to be flushed off the screen. The area of plate exposed due to lost debris can be described as that portion exposed on the right side of Figure I.1.1 (prior to retrieval, this screen area may have been covered) that still has some residual debris and is within the flow area. The total plate diameter is approximately 5 in., and that exposed to the flow is 4 in. With water being observed to be removed at an accelerated rate, it may be assumed that there were holes already in the debris bed before retrieval, creating relatively small restriction to flow.

Figure I.1.1. 060406_CO_1176_BP1 Debris Bed Post-Retrieval

See also "Investigation of the Effect of Loading Sequences for Significant Head Loss Differences from Similar NUKON/CalSil Debris Beds," PNNL correspondence to NRC, regarding CalSil only debris bed formation.

I.2 Quick-Look Report Series II Priority 2 +200% Preliminary Head Loss Test Data for PNNL Benchtop Test 060512

All data are preliminary. Test conditions are reported in Table I.2.1 and preliminary test data in Tables I.2.2-I.2.4 and Figures I.2.1 through I.2.5. The data were obtained from manual recordings taken from visual observation of the DAS screen readouts. Head loss measurements were obtained from visual observation of DAS screen using the 60-second-averaged meter readouts. The value reported is from the differential pressure (DP) meter with the most appropriate span for the given range of head loss readings. The head loss data presented have not had cold-leg/hot-leg temperature corrections applied. (The maximum attainable temperature difference between the DP legs during testing is approximately 82° to 21°C. This temperature difference equates to approximately 5 in H_2O assuming each leg is filled with water of a different temperature. Data uncertainties will be elucidated in the final report. Testing was conducted in accordance with the test plan provided by CW Enderlin (April 4, 2006, *Plans for Conducting Debris-Bed Head Loss Tests in the PNNL Large-Scale Test Loop During April 2006.* 060404 April test program memo.doc.) The test section inside diameter is 0.154 m (6.06 in.).

Table I.2.1. Test Conditions

Quick-Look Report date	6/29/06
Date of test	5/12/06
Associated test case(s)	Series II Priority 2 + 200%
Test number(s) and data file reference(s)	060512_CO_8108_LP1 060512_CO_8108_LP2 060512_CO_8108_LP3
Sump screen material installed in test section	Perforated plate. 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	4350
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	81.08
CalSil R4 target	< 1.55
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	70[(a)]
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	8
Target static pressure increase (psig)	37
Ports used for debris bed head loss measurements	U1 (10 L/Ds upstream of the test screen) D2 (10 L/Ds downstream of the test screen)
Dry retrieved debris bed mass (g)	8.09

(a) Debris bed not completely formed. Significant debris remained mobilized in flow, judged by observation of opaque flow in the test section. Bed formation judged complete at <5% change in pressure drop based on 5-min steady-state criterion.

Table I.2.2. Preliminary Data for Test 060512_CO_8108_LP1

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Bed formation	0.10	3[b]	N/A	N/A	22
Rampup 1	0.10	3	N/A	N/A	20
Rampup 1 (prefiltering)	0.20	83	N/A	N/A	20
Rampup 1 (post-filtering)	0.20	54	N/A	N/A	20
Ramp down 1	0.10	16	N/A	N/A	20
Ramp down 1	0.05	5	N/A	N/A	20
Ramp down 1	0.02	1	N/A	N/A	20
Rampup 2	0.10	17	N/A	N/A	20
Rampup 2	0.20	55	N/A	N/A	20
Ramp down 2	0.10	16	N/A	N/A	20
Ramp down 2	0.02	1	N/A	N/A	21
Rampup 3	0.10	17	N/A	N/A	20
Rampup 3	0.20	58	N/A	N/A	21
Ramp down 3	0.10	16	N/A	N/A	21
Ramp down 3	0.02	1	N/A	N/A	21
Rampup 4	0.10	17	N/A	N/A	21

(a) DP meters online during testing: 0–30, 0–150, and 0–750 in. H_2O through ramp down 1 to 0.05 ft/sec; subsequently, 0–5, 0–30, and 0–150 in. H_2O. Value from the DP meter with the most appropriate span for the given range of head loss readings.
(b) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).

Table I.2.3. Preliminary Data for Test 060512_CO_8108_LP2

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim[b] (in.)	Estimated Body[c] (in.)	
Bed Formation	0.10	N/A	N/A	N/A	N/A
Rampup 1	0.10	18	N/A	N/A	55
Rampup 1 (prefiltering)	0.20	N/A	N/A	N/A	N/A
Rampup 1 (post-filtering)	0.20	55	N/A	N/A	54
Ramp down 1	0.10	17	N/A	N/A	55
Ramp down 1	0.05	6	N/A	N/A	55
Ramp down 1	0.02	2	N/A	N/A	55
Rampup 2	0.10	18	N/A	N/A	55
Rampup 2	0.20	56	N/A	N/A	54
Ramp down 2	0.10	17	N/A	N/A	55
Ramp down 2	0.02	2	N/A	N/A	56
Rampup 3	0.10	18	N/A	N/A	55
Rampup 3	0.20	57	N/A	N/A	54
Ramp down 3	0.10	17	N/A	N/A	55
Ramp down 3	0.02	2	N/A	N/A	57
Rampup 4	0.10	18	N/A	N/A	54

(a) DP meters online during testing: 0–5, 0–30, and 0–150 in H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.

Table I.2.4. Preliminary Data for Test 060512_CO_8108_LP3

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim[b] (in.)	Estimated Body[c] (in.)	
Bed formation	0.10	N/A	N/A	N/A	N/A
Rampup 1	0.10	20	N/A	N/A	81
Rampup 1 (prefiltering)	0.20	N/A	N/A	N/A	N/A
Rampup 1 (post-filtering)	0.20	56	N/A	N/A	81
Ramp down 1	0.10	19	N/A	N/A	81
Ramp down 1	0.05	7	N/A	N/A	83
Ramp down 1	0.02	4	N/A	N/A	80
Rampup 2	0.10	21	N/A	N/A	80
Rampup 2	0.20	72	N/A	N/A	81
Ramp down 2	0.10	25	N/A	N/A	82
Ramp down 2	0.02	4	N/A	N/A	82
Rampup 3	0.10	26	N/A	N/A	82
Rampup 3	0.20	77	N/A	N/A	81
Ramp down 3	0.10	25	N/A	N/A	81
Ramp down 3	0.02	4	N/A	N/A	80
Rampup 4	0.10	27	N/A	N/A	82

(a) DP meters online during testing: 0–5, 0–30, and 0–150 in. H_2O. Value reported is from the DP meter with the most appropriate span for the given range of head loss readings.

During previous testing (e.g., Series I tests, Benchmark tests, etc.), the height of the debris bed was taken as a direct measurement at the wall of the test section. Manual measurements of this type for the CalSil-only debris bed were not obtainable given the incomplete and varied nature of the debris bed as well as the opacity of the flow. Photographs for in situ debris bed height measurements using optical triangulation were also taken. No analysis of these pictures has been conducted due to the incompleteness of the debris bed as well as the opacity of the flow restricting picture clarity.

Post-retrieval debris bed height measurements taken upon bed retrieval are provided in Table I.2.5. Results from the associated benchtop test cases conducted to determine the target debris loading for the large scale loop are presented below.

Table I.2.5. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements[a,b]			
Rim Height	Body Height	Total Bed Diameter	Body Diameter
N/A	0.08	6.065	N/A

(a) Debris bed was not complete and had an irregular surface.
(b) All measurements in inches.

Previous CalSil-only tests in the benchtop loop with a 5-mesh screen demonstrated that bulk loading had a greater probability of forming a complete debris bed than incremental debris loadings (*Investigation of the Effect of Loading Sequences for Significant Head Loss Differences from Similar NUKON/ CalSil Debris Beds*, PNNL correspondence to NRC). Benchtop testing was conducted to determine whether CalSil-only debris could be formed on a perforated plate at the JCN:N6106 Series II Priority 2 debris loading. Though an incomplete debris bed was formed, it was hypothesized that increasing the initial CalSil loading would form a complete debris bed. Individual (based on the 5-mesh tests) benchtop tests in which the CalSil loading was incrementally increased above that of Priority 2 were therefore

conducted. No attempt was made to identify the exact mass loading required for complete debris bed formation; the objective was to identify when the desired outcome was reached.

Visual observation during previous benchtop tests with the Priority 2 debris loading indicated that plus 25% loading by mass could possibly form a complete debris bed. This was not the case (see Figures I.2.6-I.2.13), and additional tests were conducted to attempt complete debris bed formation at increased loadings of 50%, 100%, and finally 200%.

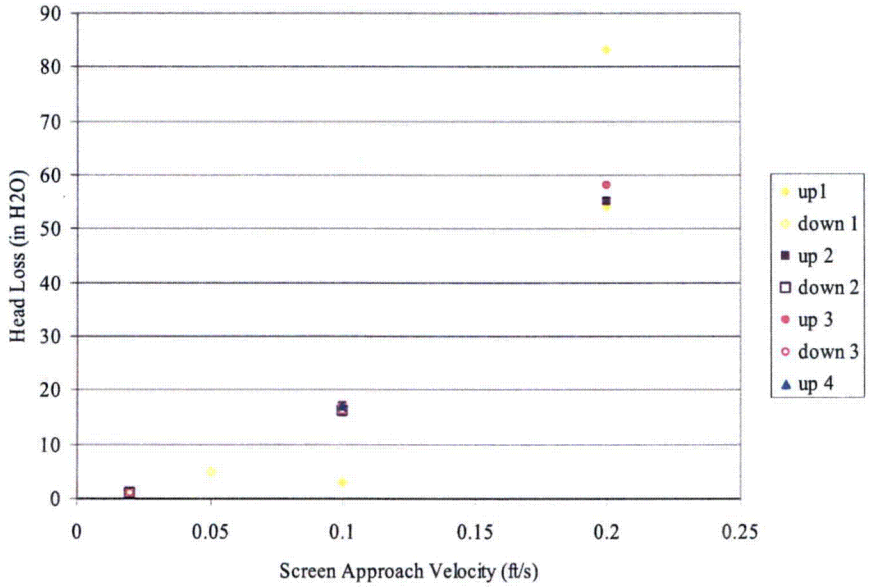


Figure I.2.1. Preliminary PNNL Data; 060512_CO_8108_LP1

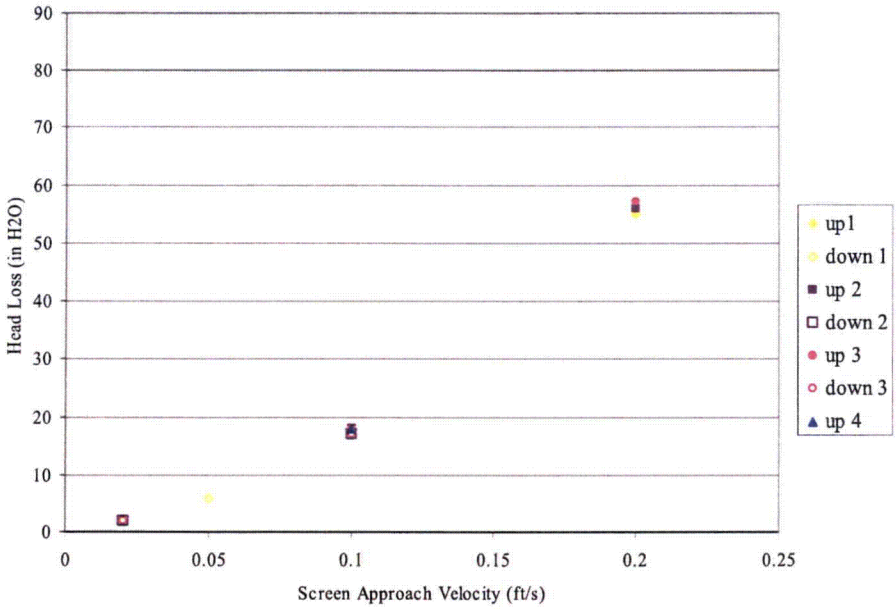


Figure I.2.2. Preliminary PNNL Data; 060512_CO_8108_LP2

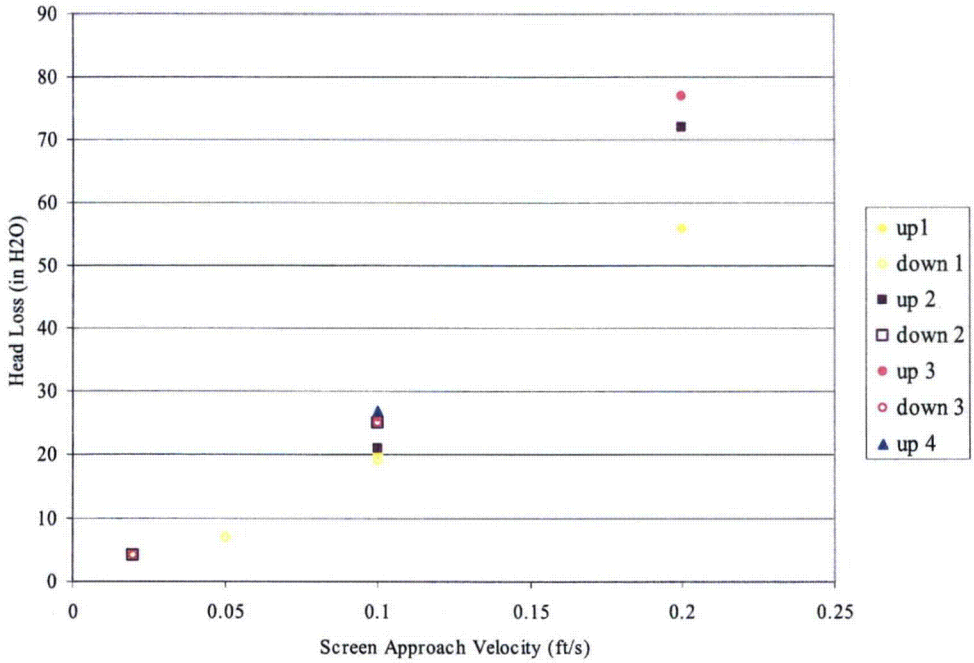


Figure I.2.3. Preliminary PNNL Data; 060512_CO_8108_LP3

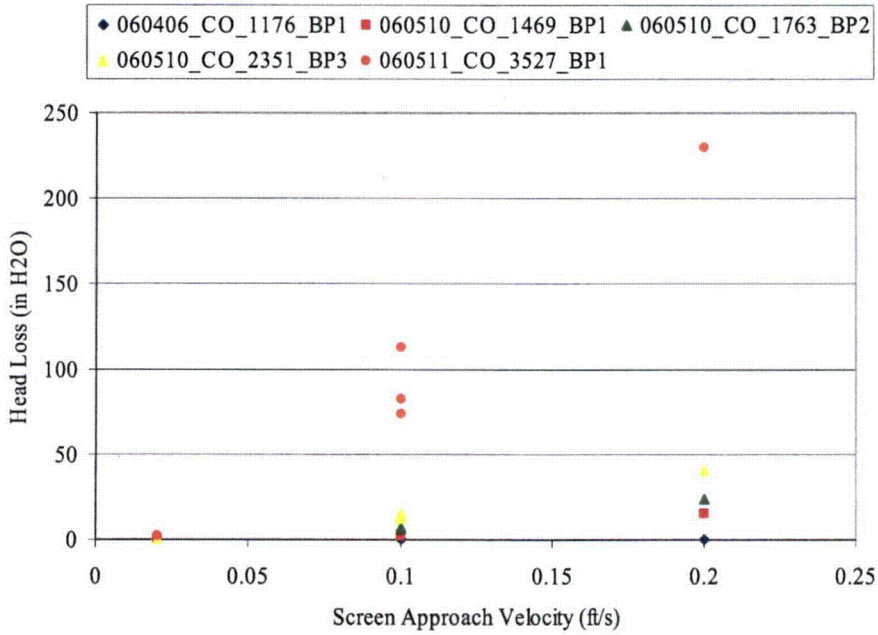


Figure I.2.4. Preliminary PNNL Data, Priority 2, Benchtop Loop

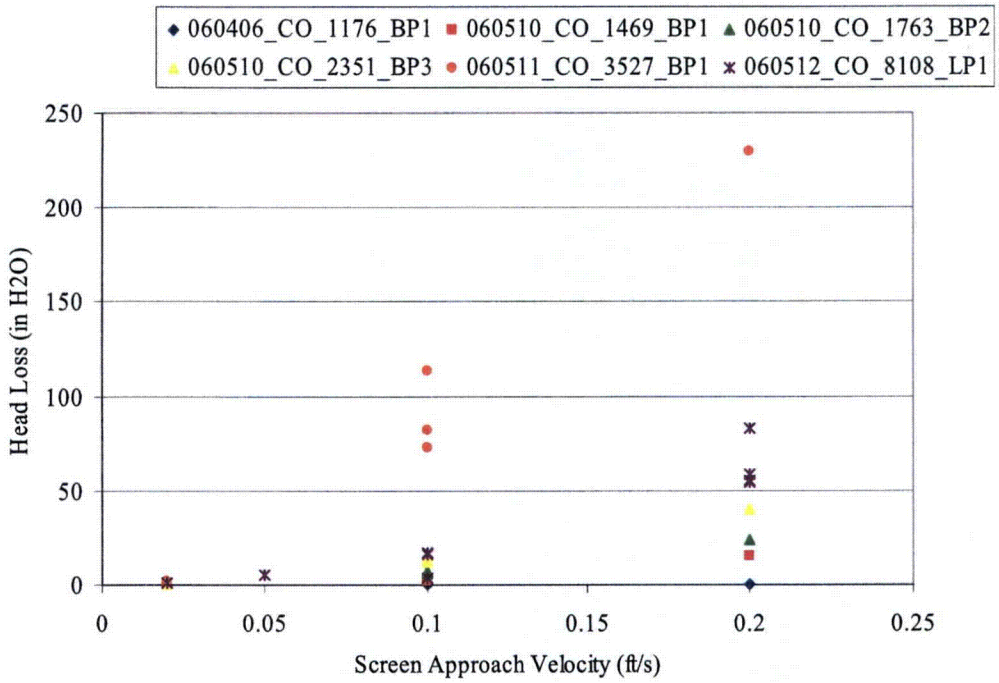


Figure I.2.5. Preliminary PNNL Data, Priority 2, Benchtop Loop and 060512_CO_8108_LP1

Figure I.2.6.060512_CO_8108_LP1, LP2, and LP3 Debris Bed in Test Section After Retrieval, Top View

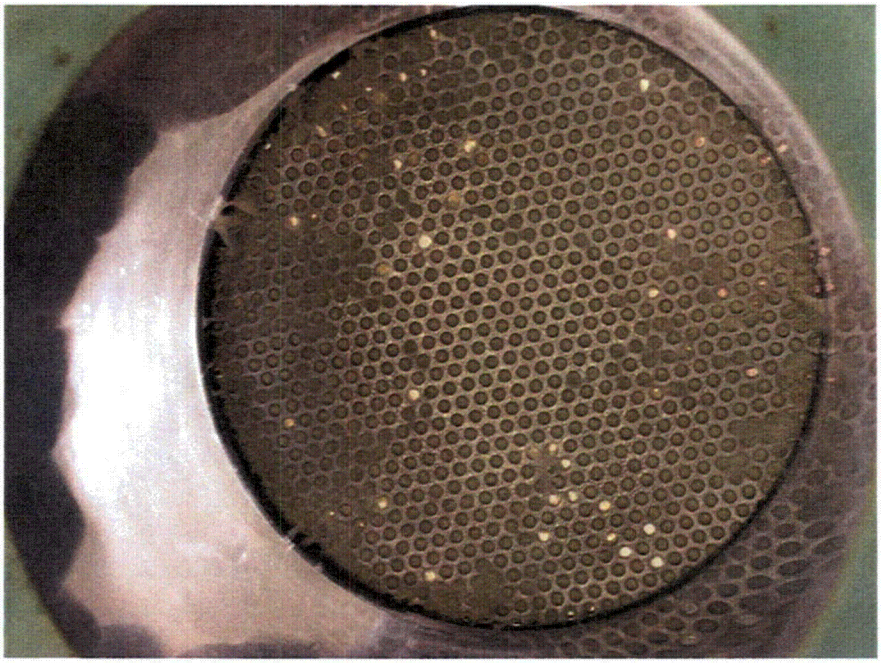


Figure I.2.7.060512_CO_8108_LP1, LP2, and LP3 Debris Bed in Test Section After Retrieval, Bottom View

Figure I.2.8. 060512_CO_8108_LP1, LP2, and LP3 Debris Bed After Retrieval from Test Section

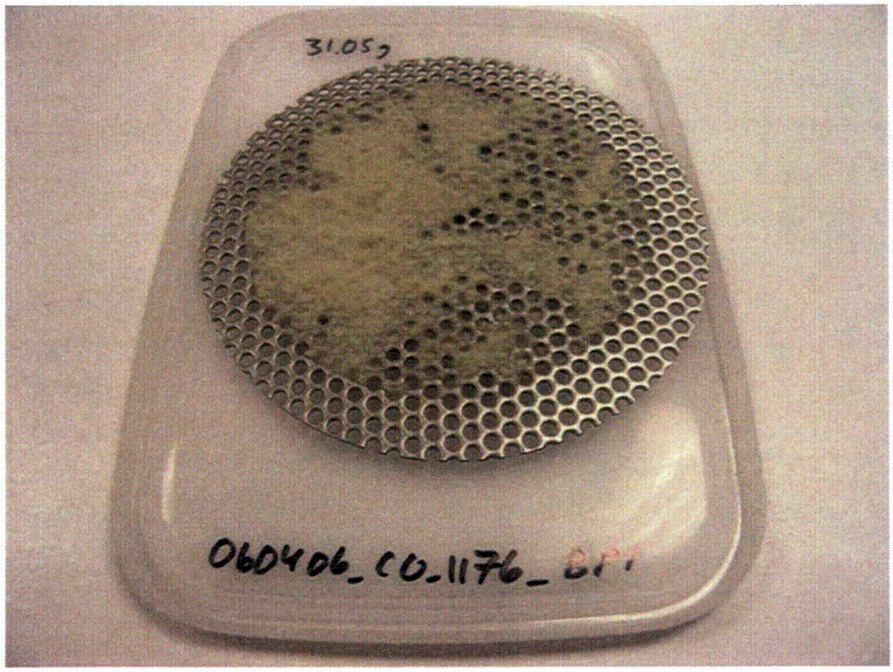


Figure I.2.9. 060406_CO_1176_BP1 Debris Bed Post-Retrieval (see Figure I.1)

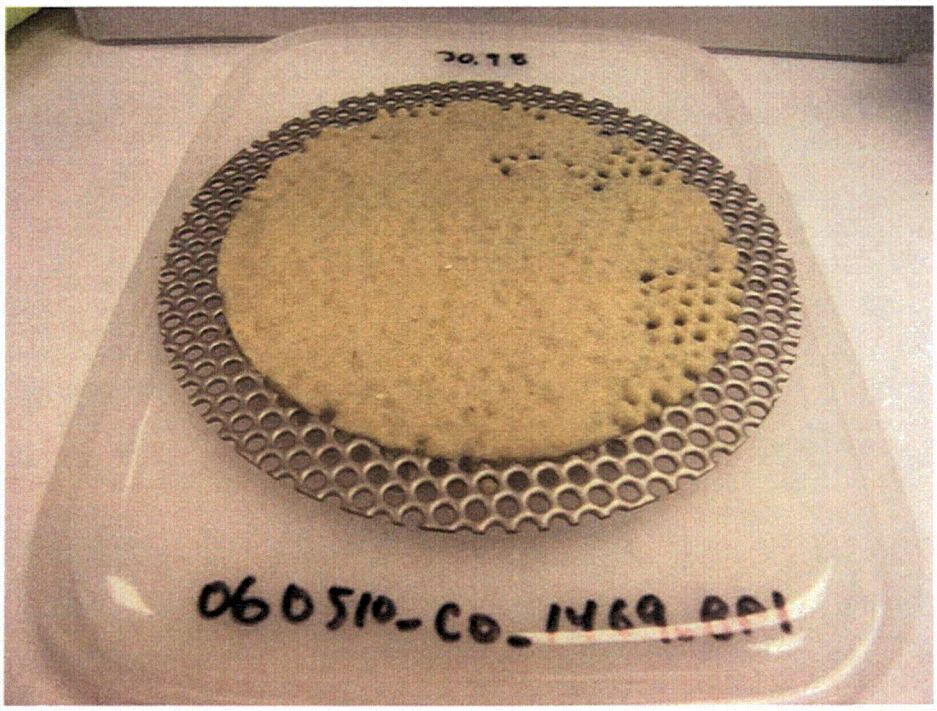


Figure I.2.10. 060510_CO_1469_BP1 Debris Bed Post-Retrieval

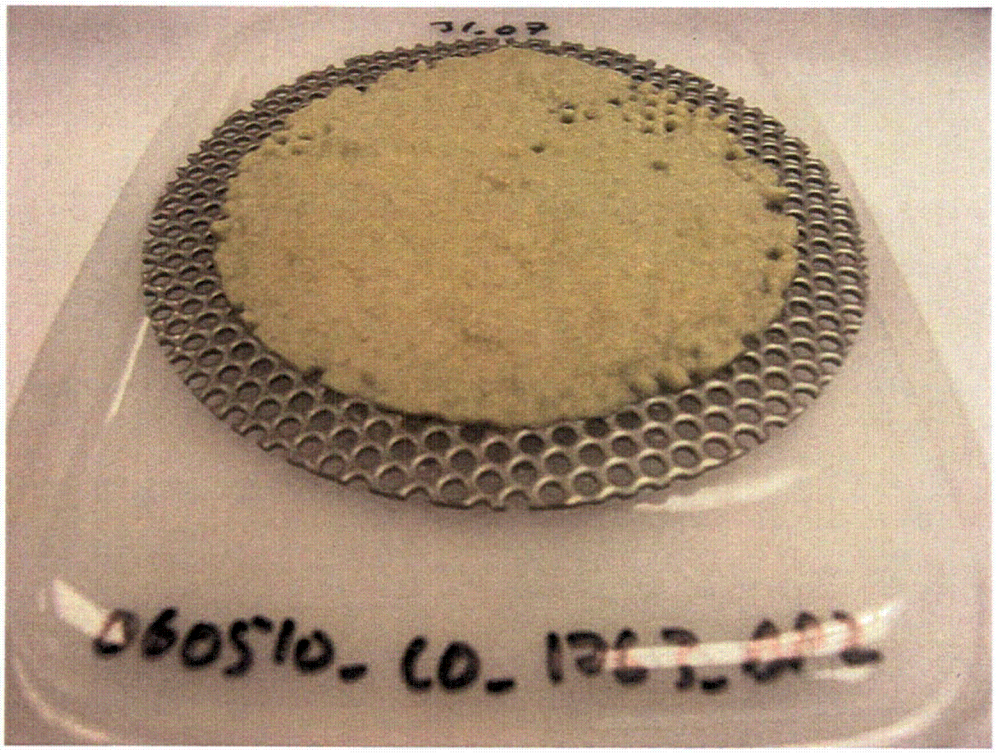


Figure I.2.11. 060510_CO_1763_BP2 Debris Bed Post-Retrieval

Figure I.2.12. 060510_CO_2351_BP3 Debris Bed Post-Retrieval

Figure I.2.13. 060511_CO_3527_BP1 Debris Bed Post-Retrieval

Test conditions for the benchtop tests are reported in Tables I.2.6–I.2.10 and preliminary test data in Tables I.11–I.15. All tests had a fluid temperature of nominally 22°C. Testing was conducted in accordance with "060404 April test program memo.doc" as applicable in the PNNL benchtop test loop and under the flow conditions in Table I.2.6–I.2.10. The benchtop loop test section inside diameter is 0.1016 m (4 in.).

Table I.2.6. Test Conditions, 060406_CO_1176_BP1

Quick-Look Report date	4/21/06
Date of test	4/6/06
Associated test case(s)	Series II Priority 2
Test number and data file reference	060406_CO_1176_BP1
Sump screen material installed in test section	Perforated plate. 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	1450
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	11.76
CalSil R4 target	< 1.55
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	20
Calculated number of representative circulations during debris bed formation (from estimated 1.5-minute circulation time)	13
Target static pressure increase (psig)	N/A, PNNL Benchtop
Ports used for debris bed head loss measurements	N/A, PNNL Benchtop
Dry retrieved debris bed mass (g)	0.64

Table I.2.7. Test Conditions, 060510_CO_1469_BP1

Quick-Look Report date	6/29/06
Date of test	5/10/06
Associated test case(s)	Series II Priority 2 + 25%
Test number and data file reference	060510_CO_1469_BP1
Sump screen material installed in test section	Perforated plate. 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	1812.5
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	14.69
CalSil R4 target	< 1.55
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	20
Calculated number of representative circulations during debris bed formation (from estimated 1.5 minute circulation time)	13
Target static pressure increase (psig)	N/A, PNNL Benchtop
Ports used for debris bed head loss measurements	N/A, PNNL Benchtop
Dry retrieved debris bed mass (g)	1.92

Table I.2.8. Test Conditions, 060510_CO_1763_BP2

Quick-Look Report date	6/29/06
Date of test	5/10/06
Associated test case(s)	Series II Priority 2 + 50%
Test number and data file reference	060510_CO_1763_BP2
Sump screen material installed in test section	Perforated plate. 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	2175
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	17.63
CalSil R4 target	< 1.55
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	20
Calculated number of representative circulations during debris bed formation (from estimated 1.5-minute circulation time)	13
Target static pressure increase (psig)	N/A, PNNL Benchtop
Ports used for debris bed head loss measurements	N/A, PNNL Benchtop
Dry retrieved debris bed mass (g)	2.37

Table I.2.9. Test Conditions, 060510_CO_2351_BP3

Quick-Look Report date	6/29/06
Date of test	5/10/06
Associated test case(s)	Series II Priority 2 + 100%
Test number and data file reference	060510_CO_2351_BP3
Sump screen material installed in test section	Perforated plate. 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	2900
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	23.51
CalSil R4 target	< 1.55
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	20
Calculated number of representative circulations during debris bed formation (from estimated 1.5 minute circulation time)	13
Target static pressure increase (psig)	N/A, PNNL Benchtop
Ports used for debris bed head loss measurements	N/A, PNNL Benchtop
Dry retrieved debris bed mass (g)	3.16

Table I.2.10. Test Conditions, 060511_CO_3527_BP1

Quick-Look Report date	6/29/06
Date of test	5/11/06
Associated test case(s)	Series II priority 2 + 200%
Test number and data file reference	060511_CO_3527_BP1
Sump screen material installed in test section	Perforated Plate. 1/8 in. ports, 3/16 in. center-to-center pitch, staggered 60° centerline pattern, 40% flow area
Target screen debris loading (g/m^2)	4350
Initial NUKON mass introduced (g)	0.0
NUKON R4 target	N/A
Initial CalSil mass introduced (g)	35.27
CalSil R4 target	< 1.55
Debris loading sequence	N/A
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	20
Calculated number of representative circulations during debris bed formation (from estimated 1.5-minute circulation time)	13
Target static pressure increase (psig)	N/A, PNNL Benchtop
Ports used for debris bed head loss measurements	N/A, PNNL Benchtop
Dry retrieved debris bed mass (g)	5.87

Table I.2.11. Preliminary Data, 060406_CO_1176_BP1

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)
Bed Formation	0.10	0.0
Rampup 1	0.20	0.1

Table I.2.12. Preliminary Data, 060510_CO_1469_BP1

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)
Bed Formation	0.10	2
Rampup 1	0.20	15
Ramp down 1	0.10	3
Ramp down 1	0.02	0
Rampup 2	0.10	3

Table I.2.13. Preliminary Data, 060510_CO_1763_BP2

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)
Bed Formation	0.10	7
Rampup 1	0.20	24
Ramp down 1	0.10	6
Ramp down 1	0.02	0
Rampup 2	0.10	7

Table I.2.14. Preliminary Data, 060510_CO_2351_BP3

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)
Bed Formation	0.10	15
Rampup 1	0.20	40
Ramp down 1	0.10	12
Ramp down 1	0.02	0
Rampup 2	0.10	13

Table I.2.15. Preliminary Data, 060511_CO_3527_BP1

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)
Bed Formation	0.10	113
Rampup 1	0.20	230
Ramp down 1	0.10	73
Ramp down 1	0.02	2
Rampup 2	0.10	82