Appendix J – NUKON-CalSil Quick Looks

Appendix J – NUKON-CalSil Quick Looks

J.1 Quick-Look Report for PNNL Test 060427_NC_0252_LP1, Test Condition Series 2 Priority 7 Preliminary PNNL Head Loss Test Data

All data herein are preliminary. Test conditions are reported in Table J.1.1, and preliminary test data in Table J.1.2 and Figure J.1.1. 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 the 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.[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 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.

Manual debris bed height measurements are reported in Table J.1.2. 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 J.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. 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 J.4. 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. Figures J.2–J.4 are photographs of the debris beds.

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[a] Temperature differences attainable between the DP "legs" during testing can effect 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 J.1.1. Test Conditions

Quick-Look Report Date	9/8/06
Date of test	4/27/06
Associated test case(s)	Series 2 Priority 7
Test number(s) and data file reference(s)	060427_NC_0252_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)	135
Initial NUKON mass introduced (g)	2.01
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	0.50
CalSil R4 target	< 1.55, no chunks
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop.
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	71
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)	1.05

Table J.1.2. Preliminary Data

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	2[c]	0.10	0.10	21
Rampup 1	0.10	2	0.10	0.10	21
Rampup 1 (prefiltering)	0.20	4	0.10	0.10	22
Rampup 1 (post-filtering)	0.20	4	0.10	0.10	21
Ramp down 1	0.10	1	0.10	0.10	21
Ramp down 1	0.02	>0.2	0.10	0.10	22
Rampup 2	0.10	1	0.10	0.10	22

(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) Pressure measurement taken prior to 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 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 J.1.3. Post-Retrieval Debris Bed Measurements

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

Table J.1.4. 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
No Analysis						

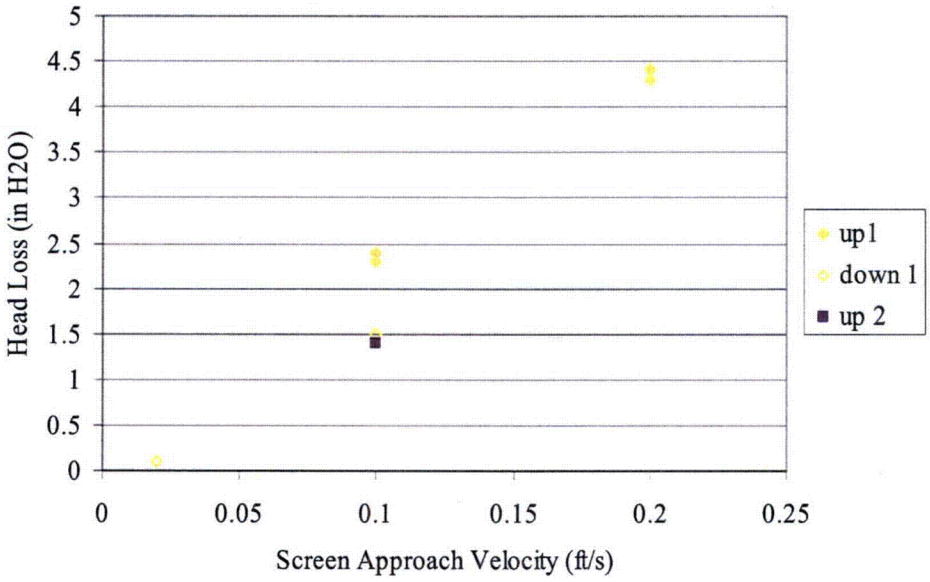

Figure J.1.1. Preliminary PNNL Data

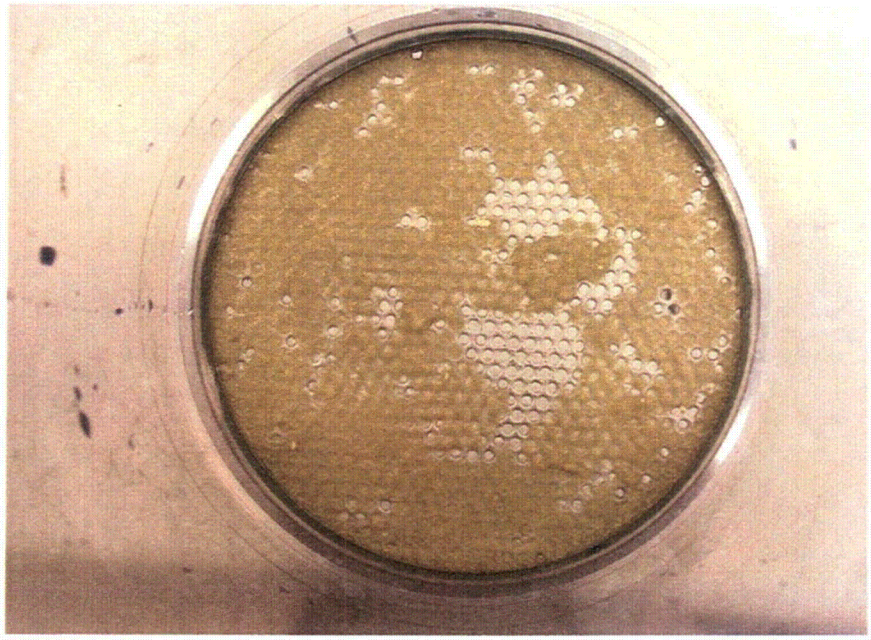

Figure J.1.2. Debris Bed in Test Section After Retrieval, Top View; Incomplete Debris Bed

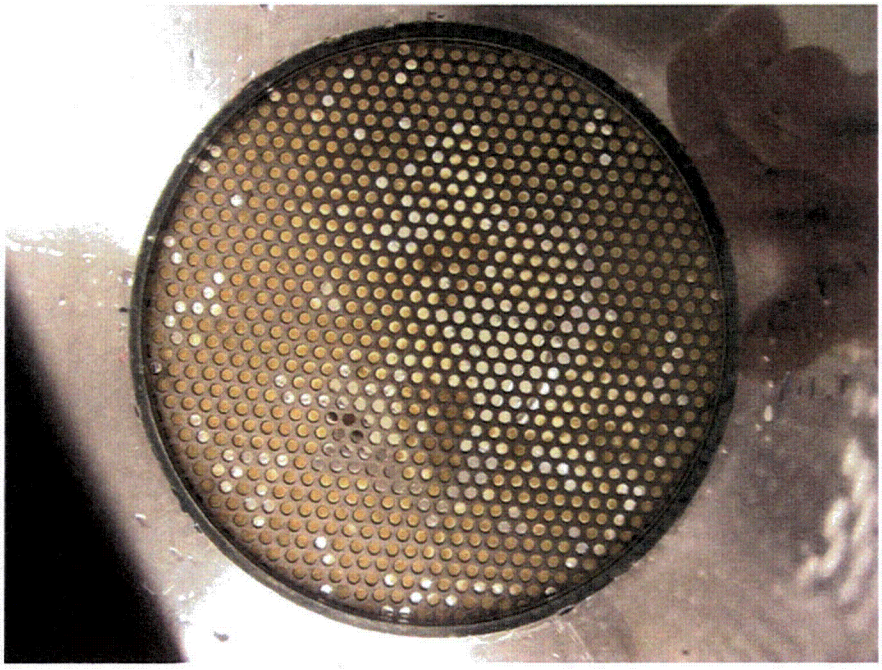

Figure J.1.3. Debris Bed in Test Section After Retrieval, Bottom View; Incomplete Debris Bed

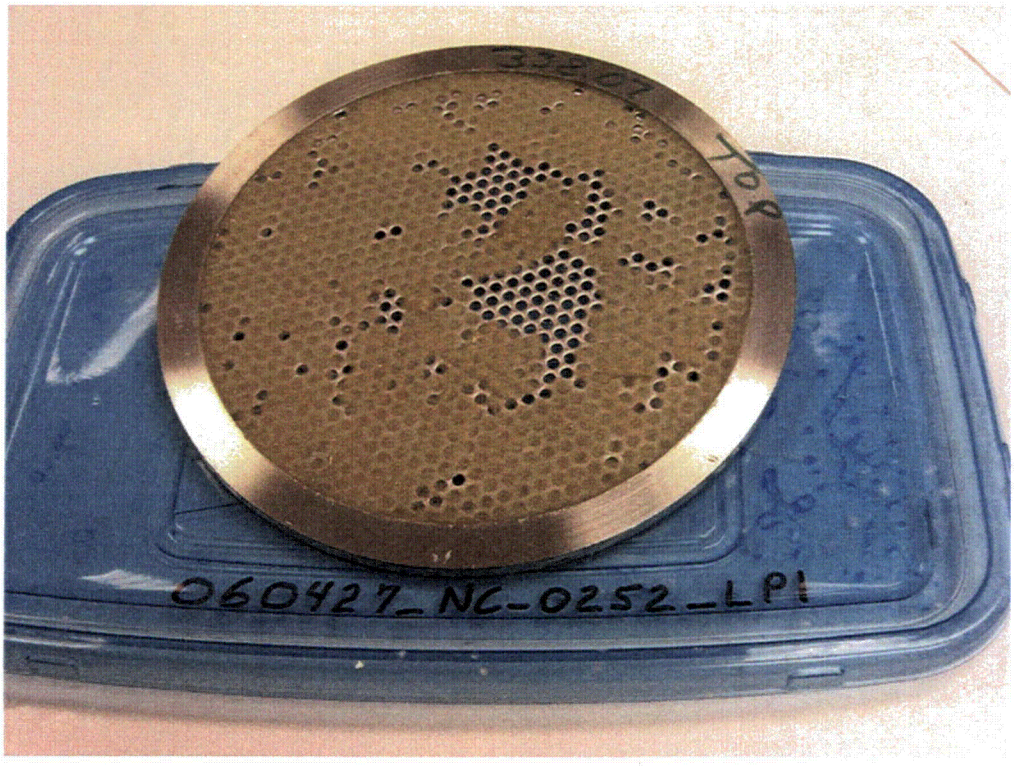

Figure J.1.4. Debris Bed After Retrieval from Test Section; Incomplete Debris Bed

J.2 Preliminary PNNL Evaluation of Bench Top Coatings Test Priority No.5, 060428_NC_0453_LP1

This test was conducted with ALK coating 1/4-inch-square and process to obtain knowledge and experience associated with handling and testing with the coatings materials. The target debris loading was ALK-1/4-in.^{2}, 0.7 kg/m^2; ALK-processed 0.7 kg/m^2. The total target debris loading was 1.4 kg/m^2. A debris bed was formed with the coatings material in the benchtop loop. Despite observation of a small number of open channels, a head loss in excess of 100-in. H_2O was measured for an approach velocity of 0.20 ft/sec. A photo of the paint chip debris bed after draining but prior to retrieval from the test loop is presented in Figure J.2.1. Photos of the retrieved debris bed are shown in Figures J.2.2 and J.2.3. The edge view shown in Figure J.2.3 allows the penetration of the paint chip into the perforated plate to be observed.

The following items were determined from the initial benchtop test with paint chips.

- The paint chips when wet have a tendency to adhere easily to surfaces. Therefore, when premixing constituents, 1/4-inch-square material was placed dry in a mixing container and the other slurried constituents added wet to the paint chips. For this initial test, the 1/4-inch-square material had been added to water before mixing with the processed material.

Figure J.2.1. Paint Chip Debris Bed from Test 060428_PQC_1136_BP1 before Removing Debris Bed from Test Section. The target debris loading was 1.4 kg/m^2 with a 1 to 1 ratio of 1/4-inch-square to processed material.

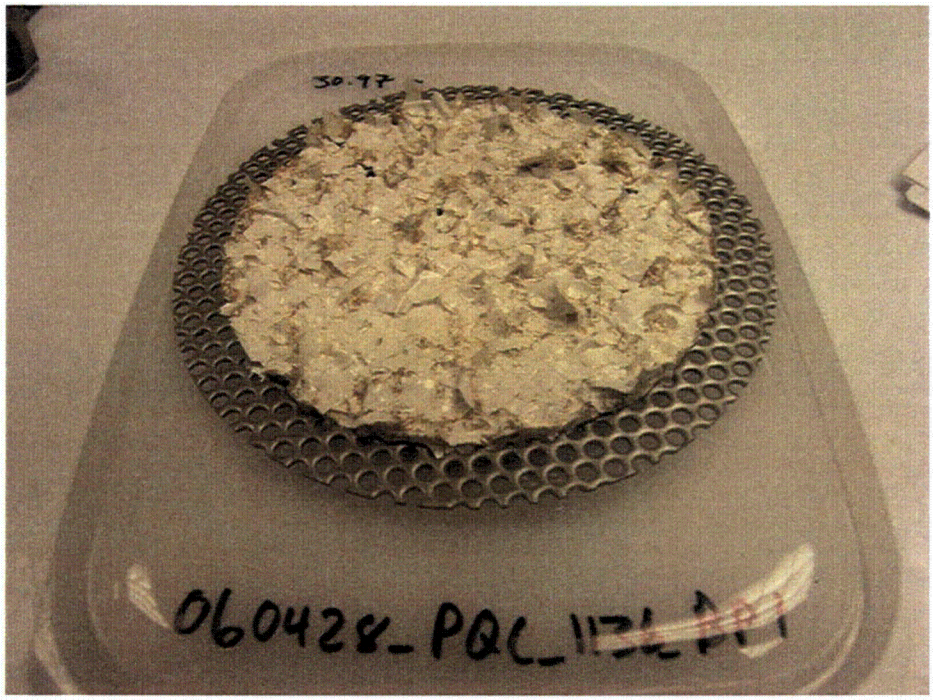

Figure J.2.2. Paint Chip Debris Bed from Test 060428_PQC_1136_BP1 Retrieved from Benchtop Test Loop. The target debris loading was 1.4 kg/m^2 with a 1 to 1 ratio of 1/4-inch-square to processed material.

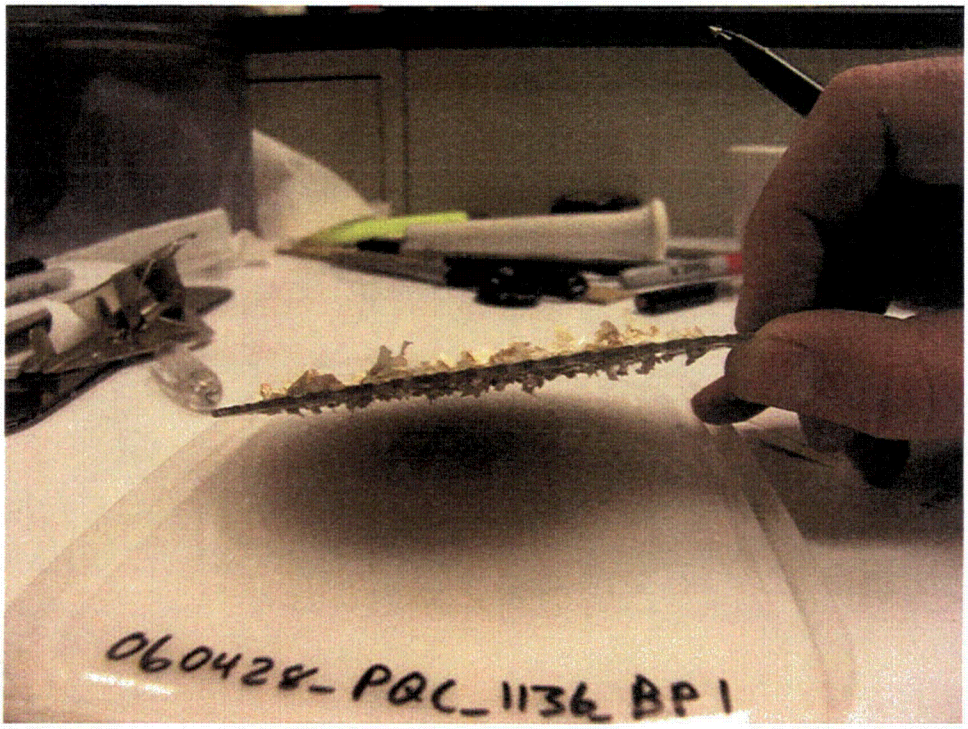

Figure J.2.3. Edge View of Retrieved Paint Chip Debris Bed from Test 060428_PQC_1136_BP1

- An approach velocity of 0.1 ft/sec is not fast enough to transport material to the test screen. Initially, the injection line velocity had been set to 0.8 ft/sec with an approach velocity of 0.1 ft/sec. Negligible paint chip material was transported to the test screen even with significant line agitation. The paint chip material exited the injection line as a saltation flow and immediately settled upon being introduced to the mainline flow. Some material transport was achieved when the approach velocity was increased to approximately 1.5 ft/sec. For the next test, the initial injection line velocity will be 1 ft/sec and the screen approach velocity 0.2 ft/sec.
- A significant amount of paint chip material was retained throughout the test loop. A significant effort may be required to remove the residual paint chip material following each test.
- The debris bed stayed intact during retrieval; therefore, the retrieval procedure used for NUKON/CalSil beds will remain unchanged for the paint chip operations.

J.3 Quick-Look Report for PNNL Test 051110_NC_ 0595_L1, Test Condition LANL-6h

No comparable data from the PNNL benchtop loop exist for this case. The debris bed was ruptured upon post-test retrieval; however, the retrieved debris bed allowed for post-test dimensions to be taken regardless of the rupture. The post-test dry mass measurements will be affected. 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 are preliminary and were obtained from manual recordings of visual observation of the DAS screen readouts (see Table J.3.2 and Figures J.3.1–J.3.2). In Table J.3.3, 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 rim of material against the wall of the test section that was thicker than the body of the debris bed. 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 where a difference in the backlighting was observed through the rim.

Test conditions are listed in Table J.3.1 and manual debris bed height measurements in Table J.3.4. 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 between approximately 0.06 and 0.08 in. below this datum. Therefore, 0.06 in. has been added to the reported measurements.

No debris bed height measurements could be taken during the test due to the extremely thin debris bed formed. Post-retrieval measurements are provided in Table J.3.4. The annular ring is not highly distinct. Figures J.3.3–J.3.5 are photographs of the debris beds.

Table J.3.1. Test Conditions

Quick-Look Report date	11/14/05
Date of test	11/10/05
Associated test case(s)	LANL: 6h
Test number and data file reference	051110_NC_0595_L1
Target screen debris loading (g/m^2)	326.1
Initial NUKON mass introduced (g)	3.97
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	1.98
CalSil R4 target	1.6–1.9
Initial bed formation screen approach velocity (ft/sec)	0.20
Final bed formation screen approach velocity (ft/sec)	0.16
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)	4.04[(a)]
(a) Mass was lost from debris bed by rupture during retrieval.	

Table J.3.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)	Fluid Temperature (°C)
Rampup 1	0.16[(a)]	15	23
	0.2[(a)]	24	21
	0.2	26	21
	0.25	33	23
	0.3	44	23
	0.36	50	23
	0.38	57	23
	0.45	68	23
Ramp down 1	0.36	51	23
	0.3	49	23
	0.25	36	23
	0.2	27	23
Rampup 2	0.25	38	23
	0.3	44	23
	0.35	54	23
	0.41	71	23
Ramp down 2	0.36	59	23
	0.3	52	23
	0.26	43	23
	0.2	29	24
Rampup 3	0.25	35	23
	0.29	46	24
	0.36	62	24
	0.41	76	24
Ramp down 3	0.36	69	24
	0.3	56	24
	0.25	46	24
	0.2	34	24
Rampup 4	0.3	52	24
	0.4	86	24
Ramp down 4	0.31	58	24
	0.2	34	24
Rampup 5	0.41	88	24
Ramp down 5	0.35	76	24
	0.3	62	24
	0.26	50	24
	0.2	41	25
	0.1	17	25
	0.05	4	25
	0.02	0	25
Rampup 6	0.1	15	25
	0.21	38	24

(a) Prior to increase of loop static pressure (~2.5 atm)

Table J.3.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.16	15	23	21
	0.2	24	21	21
	0.2	26	21	21
	0.25	33	23	21
	0.3	44	23	21
	0.36	50	23	21
	0.38	57	23	21
	0.45	68	23	21
Ramp down 1	0.36	51	23	21
	0.3	49	23	21
	0.25	36	23	21
	0.2	27	23	21
Rampup 2	0.25	38	23	21
	0.3	44	23	21
	0.35	54	23	21
	0.41	71	23	21
Ramp down 2	0.36	59	23	21
	0.3	52	23	21
	0.26	43	23	21
	0.2	29	24	21
Rampup 3	0.25	35	23	21
	0.29	46	24	21
	0.36	62	24	21
	0.41	76	24	21
Ramp down 3	0.36	69	24	21
	0.3	56	24	21
	0.25	46	24	21
	0.2	34	24	21
Rampup 4	0.3	52	24	21
	0.4	86	24	21
Ramp down 4	0.31	58	24	21
	0.2	34	24	21
Rampup 5	0.41	88	24	21
Ramp down 5	0.35	76	24	21
	0.3	62	24	21
	0.26	50	24	21
	0.2	41	25	21
	0.1	17	25	21
	0.05	4	25	21
	0.02	0	25	21
Rampup 6	0.1	15	25	21
	0.21	24	24	21

Table J.3.4. Post-Retrieval Debris Bed Measurements

Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.16	0.08	6.06	5.98

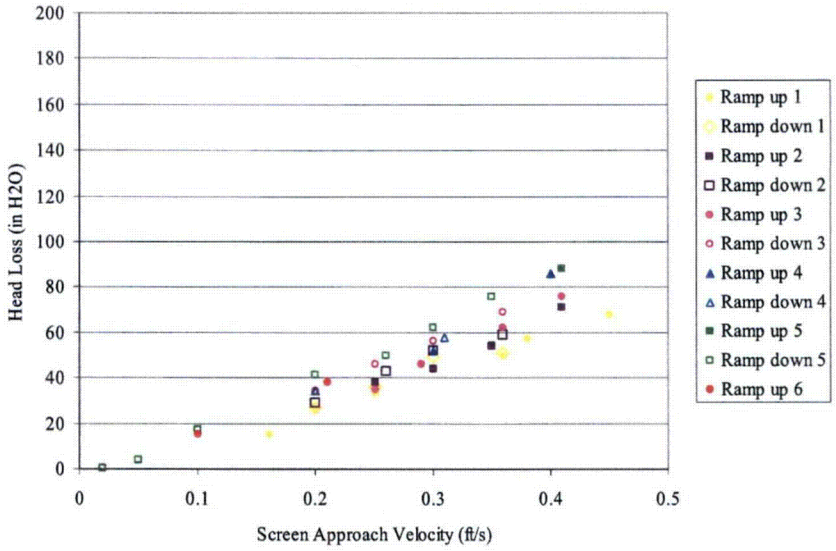

Figure J.3.1. Preliminary PNNL Data

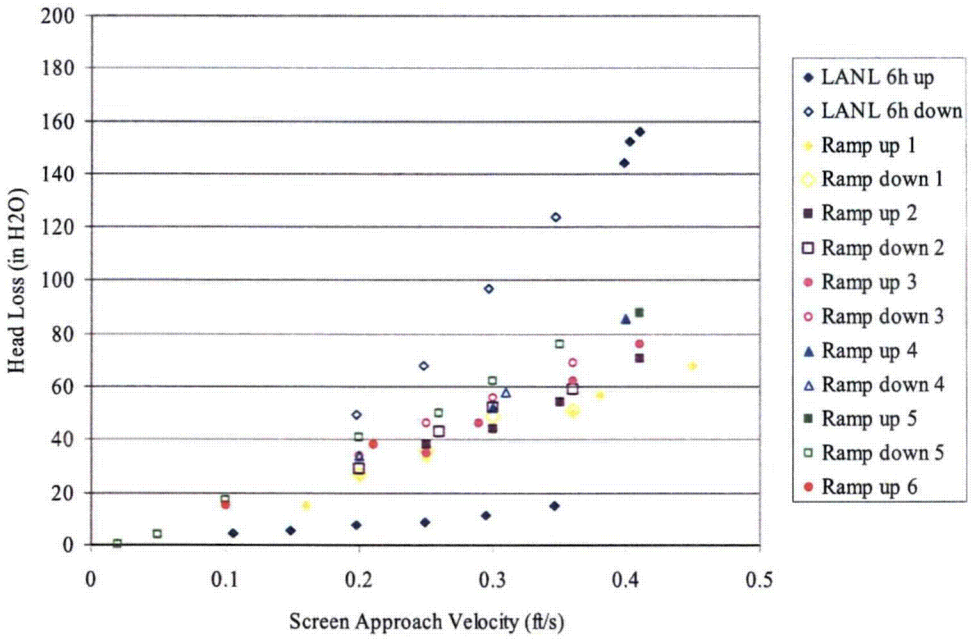

Figure J.3.2. Comparison of Preliminary PNNL Data and Previous Results

Figure J.3.3. Ruptured 051110_NC_0595_L1 Debris Bed After Draining; Rupture Caused Post-Test

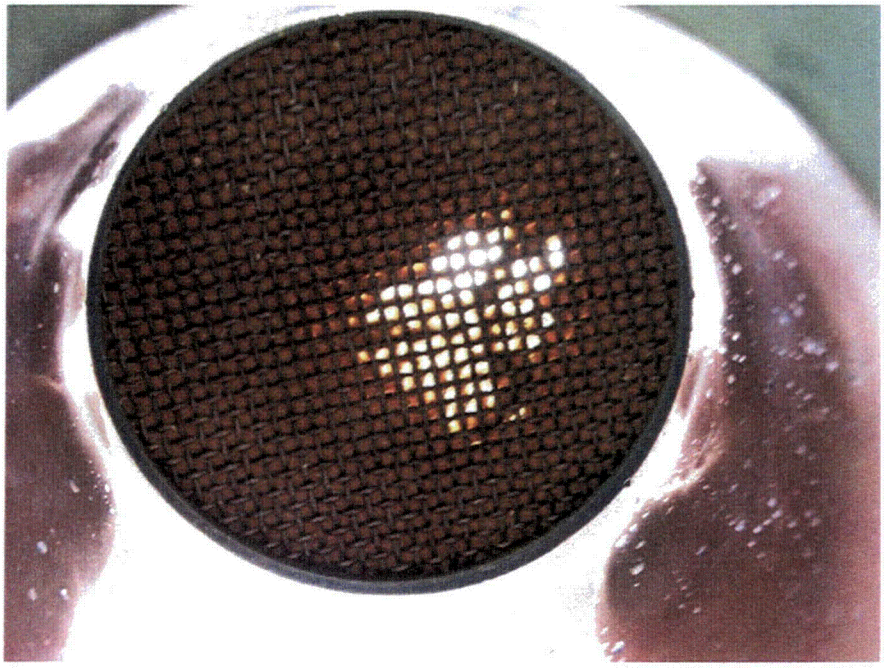

Figure J.3.4. Ruptured 051110_NC_0595_L1 Debris Bed in Test Section After Retrieval, Bottom View; Rupture Caused Post-Test

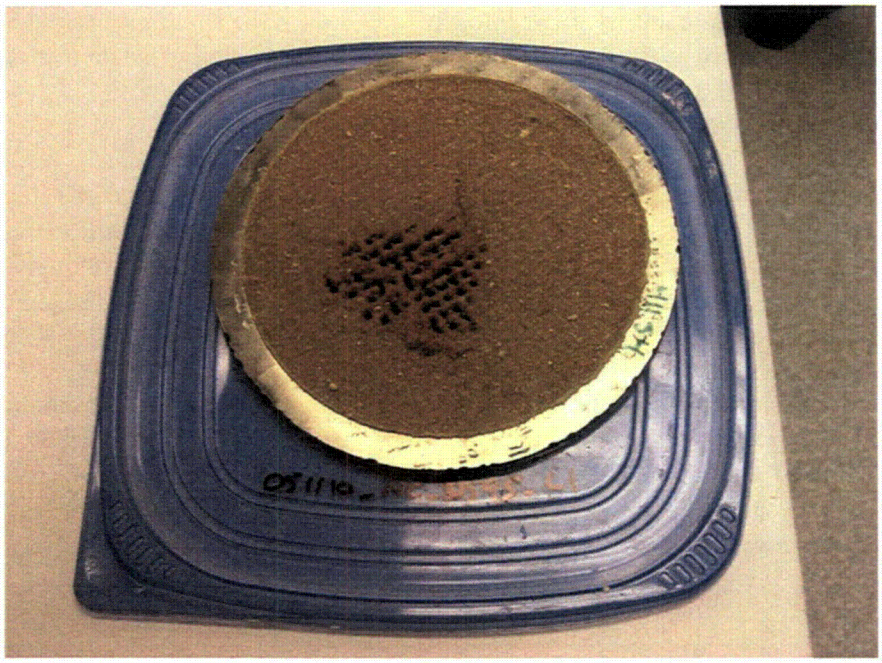

Figure J.3.5. Ruptured 051110_NC_0595_L1 Debris Bed After Retrieval from Test Section; Rupture Caused Post-Test

J.4 Quick-Look Report for PNNL Test 060509_NC_0505_LP1, Test Condition Series 2 Priority 9

All data herein are preliminary. Test conditions are reported in Table J.4.1 and Figure J.4.1 and preliminary test data in Table J.4.2. 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 Table J.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. 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 and communication with the client.[a] 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 is observed through the rim. 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.

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[a] 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.

Manual debris bed height measurements are reported in Table J.4.4. 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 J.4.5. 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 J.4.5. These data represent 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. Figures J.4.2 through J.4.4 are photographs of the debris bed.

Table J.4.1. Test Conditions

Quick-Look Report Date	9/8/06
Date of test	5/9/06
Associated test case(s)	Series 2 Priority 9
Test number(s) and data file reference(s)	060509_NC_0505_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)	271
Initial NUKON mass introduced (g)	4.04
NUKON R4 target	10 - 12
Initial CalSil mass introduced (g)	1.01
CalSil R4 target	< 1.55, no chunks
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop.
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	86
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	10
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)	3.89

Table J.4.2. Preliminary Data

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	7[c]	0.34	-	20
Rampup 1	0.10	7	0.34	-	21
Rampup 1 (pre filtering)	0.20	18	0.34	-	21
Rampup 1 (post-filtering)	0.20	20	0.34	-	21
Ramp down 1	0.10	9	0.34	-	21
Ramp down 1	0.05	4	0.34	-	21
Ramp down 1	0.02	1	0.34	-	21
Rampup 2	0.10	9	0.34	-	21
Rampup 2	0.20	22	0.34	-	21
Ramp down 2	0.10	10	0.34	-	21
Ramp down 2	0.02	1	0.34	-	21
Rampup 3	0.10	10	0.34	-	21
Rampup 3	0.20	23	0.34	-	21
Ramp down 3	0.10	10	0.34	-	21
Ramp down 3	0.02	1	0.34	-	21
Rampup 4	0.10	10	0.34	-	22

(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 that shows through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.
(c) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).

Table J.4.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	7	21	17
Rampup 1	0.10	7	21	18
Rampup 1 (prefiltering)	0.20	18	21	19
Rampup 1 (post-filtering)	0.20	20	21	19
Ramp down 1	0.10	9	21	19
Ramp down 1	0.05	4	21	20
Ramp down 1	0.02	1	21	20
Rampup 2	0.10	9	21	20
Rampup 2	0.20	22	21	20
Ramp down 2	0.10	10	21	21
Ramp down 2	0.02	1	21	21
Rampup 3	0.10	10	21	21
Rampup 3	0.20	23	21	21
Ramp down 3	0.10	10	21	21
Ramp down 3	0.02	1	25	21
Rampup 4	0.10	10	21	21

Table J.4.4. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	**Body Height (in.)**	**Total Bed Diameter (in.)**	**Body Diameter (in.)**
0.22	0.07	6.065	N/A

Table J.4.5. 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**
060509_LP1_0.1_15_RU1	0.21	0.13	0.11	5.11	2.26	3.60
060509_LP1_0.2_17_RU1	0.20	0.11	0.09	5.23	1.94	3.01
060509_LP1_0.2_26_RU3	0.18	0.10	0.08	5.38	1.82	2.62
060509_LP1_0.02_28_RD3	0.19	0.12	0.10	5.32	2.23	3.19
060509_LP1_0.1_29_RU4	0.18	0.11	0.09	5.32	2.00	2.90

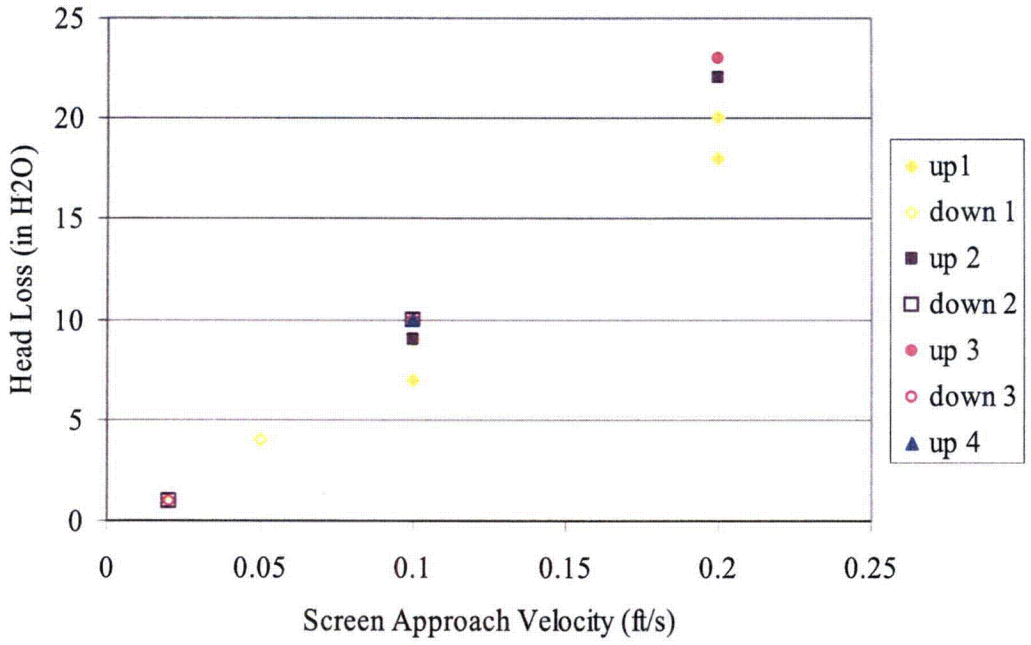


Figure J.4.1. Preliminary PNNL Data

Figure J.4.2. Debris Bed in Test Section After Retrieval, Top View; Disturbed Post-Test

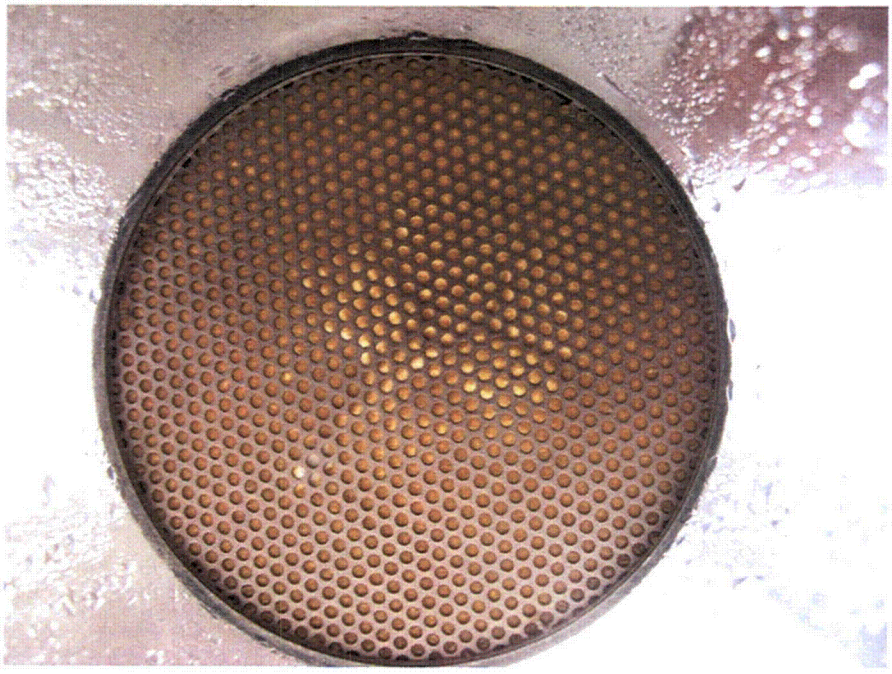


Figure J.4.3. Debris Bed in Test Section After Retrieval, Bottom View; Disturbed Post-Test

Figure J.4.4. Debris Bed After Retrieval from Test Section; Disturbed Post-Test

J.5 Quick-Look Report for PNNL Tests 060426_NC_0708_LP1 and 060426_NC_0708_LP2, Test Condition Series II Priority 6

All data are considered preliminary. Test conditions are reported in Table J.5.1 and preliminary test data in Tables J.5.2 and J.5.3. The data were obtained from manual recordings of 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 DP meter with the most appropriate span for the given range of head loss readings. In Tables J.5.4 and J.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 provided test plan. 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. 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 seen showing through the rim. 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 J.5.6 and J.5.7. 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 0.0625 in. below this datum. Therefore, 0.0625 in. has been added to the reported measurements.

Table J.5.1. Test Conditions

Quick-Look Report Date	5/25/06
Date of Test	4/26/06
Associated test case(s)	Series II Priority 6
Rest number(s) and data file reference(s)	060426_NC_0708_LP1 060426_NC_0708_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)	380
Initial NUKON mass introduced (g)	4.04
NUKON R4 target	10 - 12
Initial CalSil mass introduced (g)	3.04
CalSil R4 target	< 1.55, limited by low mass, prepared to "no chunks"
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	75
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)	3.97

Table J.5.2. Preliminary Data for Test 060426_NC_0708_LP1

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	13[d]	0.26	-	23
Rampup 1	0.10	15	0.26	-	24
Rampup 1 (prefiltering)	0.20	42	0.30	-	21
Rampup 1 (post-filtering)	0.20	40	0.22	-	20
Ramp down 1	0.10	18	0.22	-	20
Ramp down 1	0.05	9	0.26	-	20
Ramp down 1	0.02	2	0.26	-	20
Rampup 2	0.10	19	0.26	-	20
Rampup 2	0.20	45	0.26	-	20
Ramp down 2	0.10	20	0.26	-	20
Ramp down 2	0.02	6	0.26	-	20
Rampup 3	0.10	20	0.26	-	20
Rampup 3	0.20	48	0.26	-	20
Ramp down 3	0.10	22	0.26	-	20
Ramp down 3	0.02	2	0.26	-	21
Rampup 4	0.10	22	0.26	-	21

(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 0.14 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 above the screen where a difference in backlighting could be observed through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.
(d) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).

Table J.5.3. Preliminary Data for Test 060426_NC_0708_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	15	0.26	--[d]	84
Rampup 1 (prefiltering)	0.20	N/A	N/A	N/A	N/A
Rampup 1 (post-filtering)	0.20	32	0.30	--	84
Ramp down 1	0.10	17	0.34	--	84
Ramp down 1	0.05	8	0.26	--	83
Ramp down 1	0.02	4	0.30	--	83
Rampup 2	0.10	15	0.26	--	81
Rampup 2	0.20	26	0.26	--	82
Ramp down 2	0.10	14	0.22	--	83
Ramp down 2	0.02	4	0.26	--	81
Rampup 3	0.10	13	0.26	--	83
Rampup 3	0.20	30	0.26	--	81
Ramp down 3	0.10	14	0.26	--	83
Ramp down 3	0.02	5	0.30	--	81
Rampup 4	0.10	13	0.26	--	82

(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 off the screen at which there was a difference in the amount of back-light which shown through the rim.
(d) Blanks entries (--) indicate that no measurement was taken as a difference in the back-lighting was not observed.

Table J.5.4. Corrected Data for Test 060426_NC_0708_LP1

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	13	23	17
Rampup 1	0.10	15	24	18
Rampup 1 (pre filtering)	0.20	42	21	16
Rampup 1 (post-filtering)	0.20	40	20	19
Ramp down 1	0.10	18	20	19
Ramp down 1	0.05	9	20	20
Ramp down 1	0.02	2	20	20
Rampup 2	0.10	19	20	20
Rampup 2	0.20	45	20	20
Ramp down 2	0.10	20	20	21
Ramp down 2	0.02	6	20	21
Rampup 3	0.10	20	20	21
Rampup 3	0.20	48	20	21
Ramp down 3	0.10	22	20	21
Ramp down 3	0.02	2	25	21
Rampup 4	0.10	22	21	21

Table J.5.5. Corrected Data for Test 060426_NC_0708_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	#N/A	20
Rampup 1	0.10	12	84	23
Rampup 1 (pre filtering)	0.20	#N/A	#N/A	24
Rampup 1 (post-filtering)	0.20	28	85	24
Ramp down 1	0.10	14	83	23
Ramp down 1	0.05	5	81	23
Ramp down 1	0.02	1	80	21
Rampup 2	0.10	12	82	21
Rampup 2	0.20	23	84	25
Ramp down 2	0.10	11	83	23
Ramp down 2	0.02	1	79	21
Rampup 3	0.10	10	81	21
Rampup 3	0.20	27	82	21
Ramp down 3	0.10	11	82	21
Ramp down 3	0.02	5	25	21
Rampup 4	0.10	10	82	20

Post-retrieval debris bed height measurements taken at bed retrieval are provided in Table J.5.6. The determination of the debris bed height from the optical triangulation technique is made by post-test analysis of digital photographs taken during the test (Figures J.5.1 and J.5.2). A series of evenly spaced parallel lines is projected onto the debris bed surface and digital pictures taken at a known fixed angle; the 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 J.5.7. 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. Figures J.5.3 through J.5.5 are photographs of the debris beds.

Table J.5.6. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.12	< 0.04	6.065	6.0

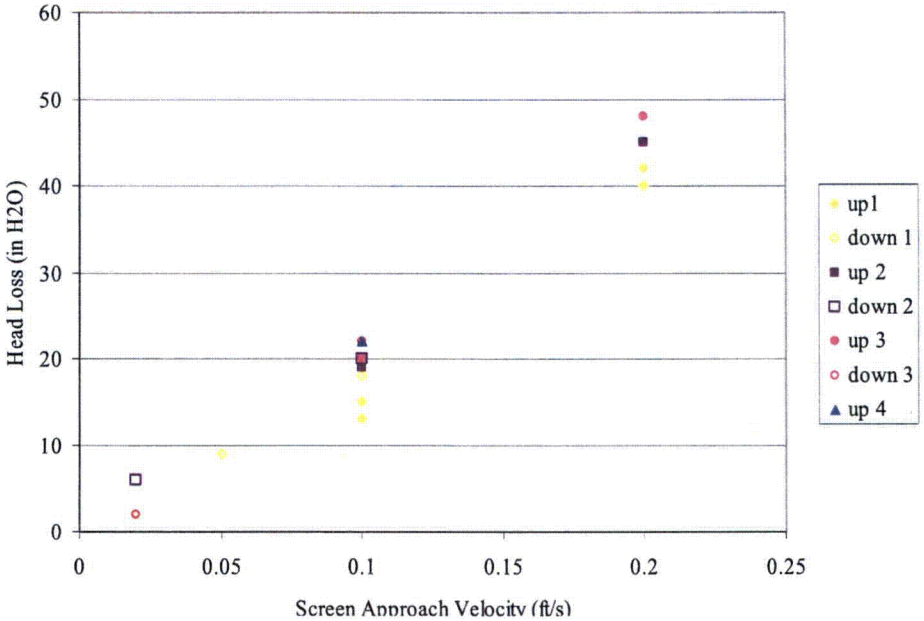


Figure J.5.1. Preliminary PNNL Data; 060426_NC_0708_LP1

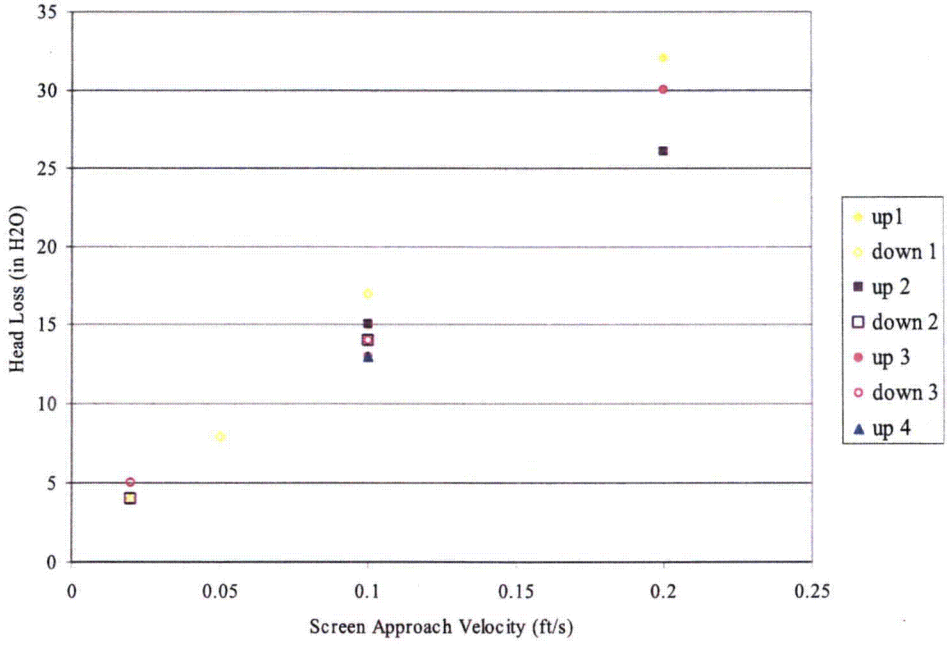


Figure J.5.2. Preliminary PNNL Data; 060426_NC_0708_LP2

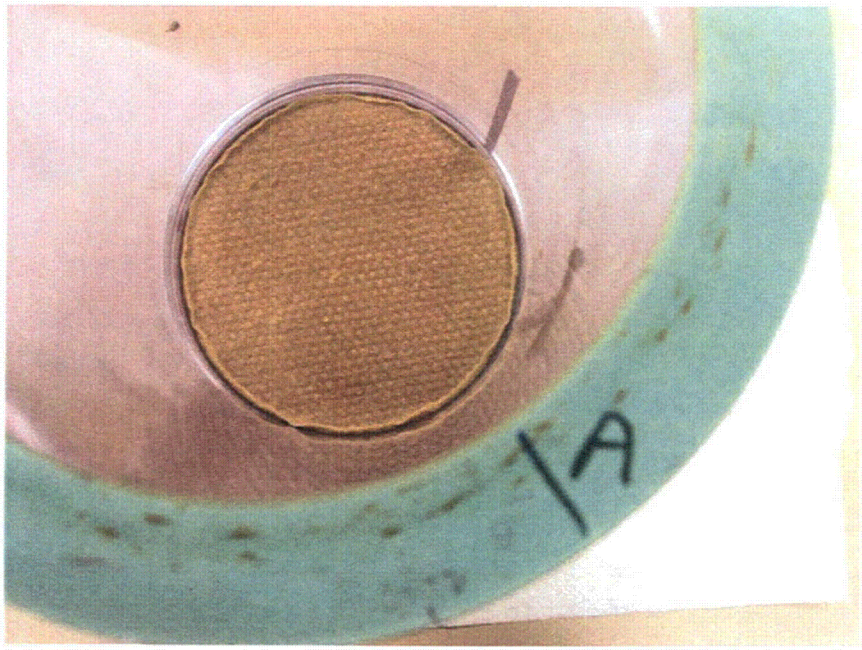


Figure J.5.3. 060426_NC_0708_LP1, LP2 Debris Bed in Test Section After Retrieval, Top View. Debris bed rim separated/rolled in from test section wall by post-retrieval handling.

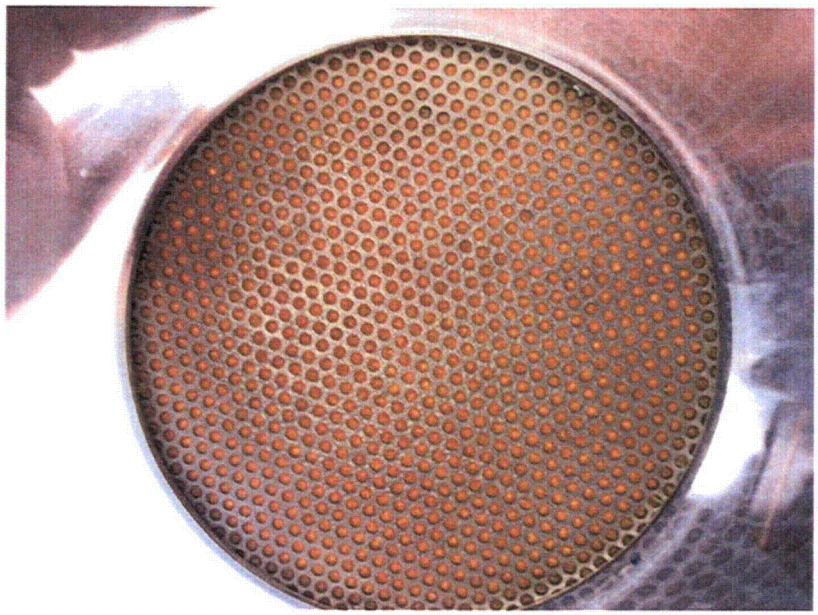


Figure J.5.4. 060426_NC_0708_LP1, LP2 Debris Bed in Test Section After Retrieval, Bottom View

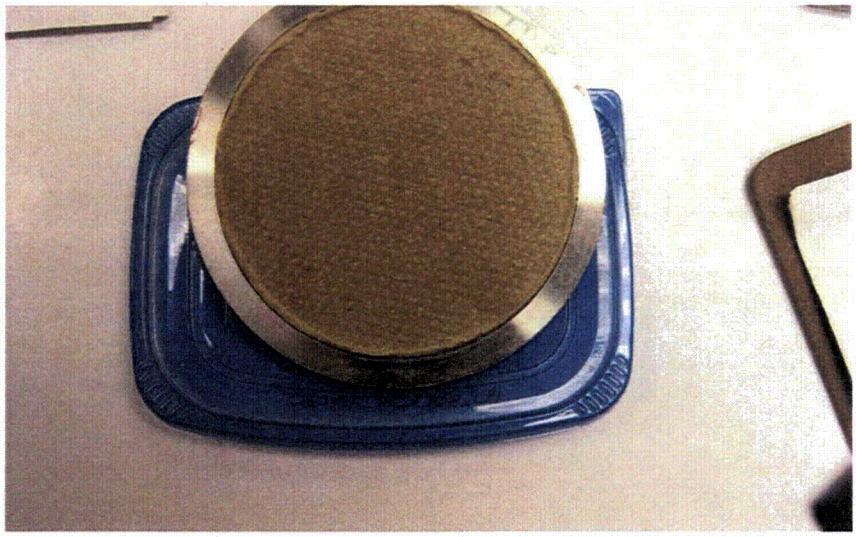


Figure J.5.5. 060426_NC_0708_LP1, LP2 Debris Bed After Retrieval from Test Section. Debris bed rim separated/rolled in from test sec

Table J.5.7. 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
060426_LP1_0.1_72_RU1	0.24	0.10	0.08	5.30	1.76	2.86
060426_LP1_0.2_74_RU1	0.22	0.08	0.06	5.18	1.26	2.36
060426_LP1_0.02_77_RD1	0.22	0.10	0.08	5.27	1.74	2.81
060426_LP1_0.2_79_RU2	0.22	0.07	0.05	5.31	1.11	2.02
060426_LP1_0.1_87_RU4	0.22	0.07	0.05	5.25	1.08	2.06
060426_LP2_0.2_98_RU3	0.20	0.06	0.04	5.32	0.89	1.69

J.6 Quick-Look Report Series II Demo 1, Tests 060517_NC_0808_LP1 and 060517_NC_0808_LP2 – PNNL Head Loss Test Data

All data are preliminary. Test conditions are listed in Table J.6.1; preliminary test data are reported in Tables J.6.2-J.6.3 and Figures J.6.1 and J.6.2. The data were obtained from manual recordings of 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 DP meter with the most appropriate span for the given range of head loss readings. In Tables J.6.4 and J.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. Testing was conducted in accordance with the provided test plan.[a] The test section inside diameter is 0.154 m (6.06 in.).

[a] 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 to WJ Krotiuk.

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 was observed through the rim. 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 J.6.6–J.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 J.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 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 J.6.7. 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. Debris bed photographs are presented in Figures J.6.3–J.6.8.

Table J.6.1. Test Conditions

Quick-Look Report date	6/9/06
Date of test	5/17/06
Associated test case(s)	Series II Demo 1
Test number(s) and data file reference(s)	060517_NC_0808_LP1 060517_NC_0808_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)	434
Initial NUKON mass introduced (g)	4.04
NUKON R4 target	10 - 12
Initial CalSil mass introduced (g)	4.04
CalSil R4 target	< 1.55
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	114
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	13
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)	5.54[(a)]

(a) Debris bed was disturbed during retrieval. Less than 5% by volume of the debris bed material, based on visual observation and comparison, may have been lost during the disturbance. See caption of Figure J.41 for disturbance description.

Table J.6.2. Preliminary Data for Test 060517_NC_0808_LP1

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim[c] (in.)	Estimated Body[d] (in.)	
Bed formation	0.10	31[b]	-	-	25
Rampup 1	0.10	31	0.31	-	25
Rampup 1 (prefiltering)	0.20	278	0.31	-	25
Rampup 1 (post-filtering)	0.20	281	-	-	25
Ramp down 1	0.10	94	0.28	-	25
Ramp down 1	0.05	28	< 0.31	-	25
Ramp down 1	0.02	5	< 0.31	-	25
Rampup 2	0.05	21	< 0.31	-	25
Rampup 2	0.10	90	< 0.31	-	25

(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) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).
(c) The debris bed rim height varied by up to approximately 0.08 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 off the screen at which a difference in backlighting was observed through the rim. Blank (--) entries indicate that no measurement was taken because no difference in backlighting was observed.

Increased head loss from rampup 1 at 0.10 ft/sec to ramp down 1 at 0.10 ft/sec screen approach velocity corresponds with visually observed changes in the debris bed. It was observed that open or less-covered perforations in the plate, as judged by the use of a backlight, were covered during the rampup 1 flow at the 0.20 ft/sec screen approach velocity. The increase of 200% from rampup 1 at 0.10 ft/sec to ramp down 1 at 0.10 ft/sec is substantially greater than observed during previous testing. Conversely, light areas were visually observed to possibly increase in number from ramp down 1 to rampup 2.

Table J.6.3. Preliminary Data for Test 060517_NC_0808_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	108	0.34	0.26	82
Rampup 1 (prefiltering)	0.20	N/A	N/A	N/A	N/A
Rampup 1 (post-filtering)	0.20	189	0.34	0.26	82
Ramp down 1	0.10	62	0.34	0.26	83
Ramp down 1	0.05	19	0.34	0.26	84
Ramp down 1	0.02	6	0.34	0.26	84
Rampup 2	0.05	19	0.34	0.26	83
Rampup 2	0.10	58	0.34	0.26	83

(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 0.04 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 off the screen at which there was a difference in the amount of backlighting showing through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.

Table J.6.4. Corrected Data for Test 060517_NC_0808_LP1

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	31	26	22
Rampup 1	0.10	31	26	22
Rampup 1 (pre filtering)	0.20	278	26	22
Rampup 1 (post-filtering)	0.20	281	26	22
Ramp down 1	0.10	94	26	22
Ramp down 1	0.05	28	26	22
Ramp down 1	0.02	5	26	22
Rampup 2	0.05	21	26	22
Rampup 2	0.10	90	26	23

Table J.6.5. Corrected Data for Test 060517_NC_0808_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	#N/A	#N/A
Rampup 1	0.10	105	82	24
Rampup 1 (pre filtering)	0.20	#N/A	#N/A	#N/A
Rampup 1 (post-filtering)	0.20	186	82	25
Ramp down 1	0.10	59	83	25
Ramp down 1	0.05	16	83	25
Ramp down 1	0.02	3	80	25
Rampup 2	0.05	16	81	25
Rampup 2	0.10	55	82	25

Table J.6.6. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements[a]			
Rim Height (in.)	Body Height (in)	Total Bed Diameter (in.)	Body Diameter (in.)
0.12	0.08	6.065	N/A

(a) Debris bed was disturbed during retrieval; debris bed surface was distorted (see caption of Figure J.6.3 for a description of the disturbance).

Table J.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
060517_LP1_0.1_97_RU1	0.29	0.11	0.09	5.18	1.90	3.38
060517_LP1_0.2_00_RU1	0.21	0.05	0.03	5.42	0.69	1.39
060517_LP1_0.02_03_RD1	0.23	0.09	0.07	5.17	1.47	2.65
060517_LP1_0.1_05_RU2	0.22	0.07	0.05	5.29	1.10	2.03
060517_LP2_0.2_07_RU1	0.23	0.07	0.05	5.19	1.06	2.14
060517_LP2_0.02_11_RD1	0.24	0.10	0.08	5.29	1.76	2.87

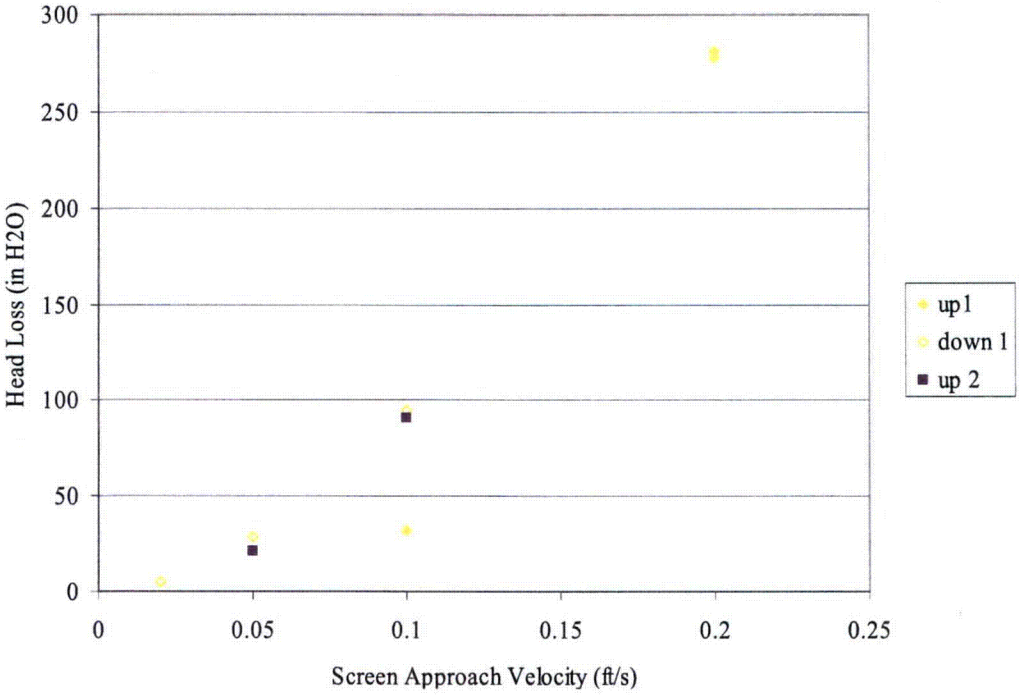


Figure J.6.1. Preliminary PNNL Data; 060517_NC_0808_LP1

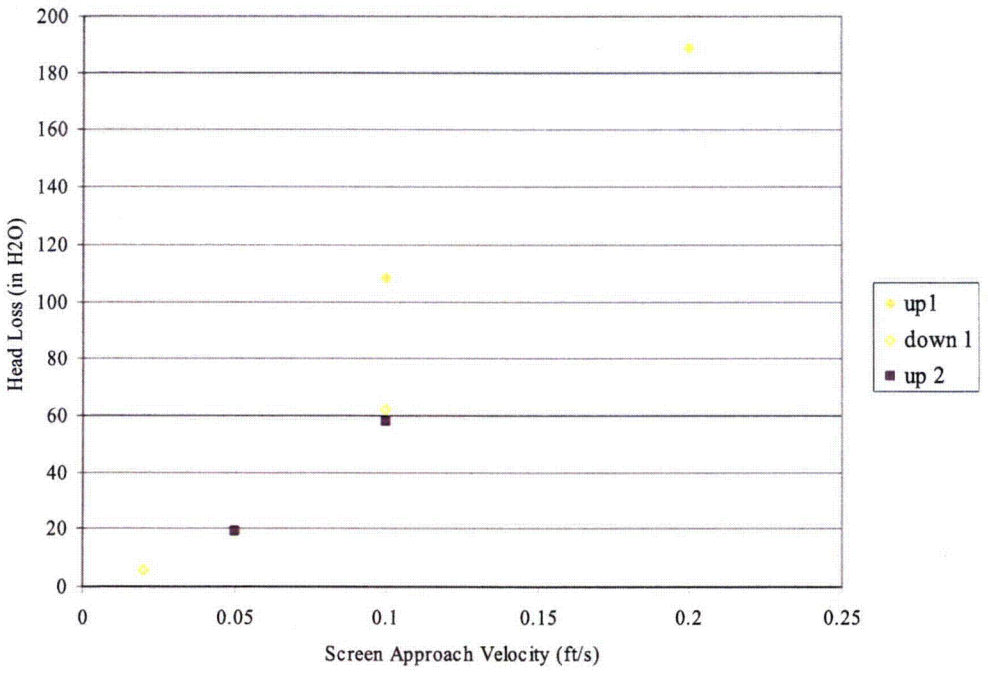


Figure J.6.2. Preliminary PNNL Data; 060517_NC_0808_LP2

Figure J.6.3. 060517_NC_0808_LP1, LP2 Debris Bed in Test Section After Retrieval, Top View. Debris bed disturbed during retrieval. Water flow down wall after uniform drainage of test section was complete visually observed to wash away some rim material (approximately 10:00 to 2:00 orientation) and deposit it nearby (to the disturbed rim). The post-draining water flow apparently caused a pock mark at the 1:30 orientation and holes at 11:00 and 2:30 orientations (see Figure J.6.4 for comparison before retrieval). The raised feature to the left-of-center of the debris bed was caused by a backflow of air up through debris bed.

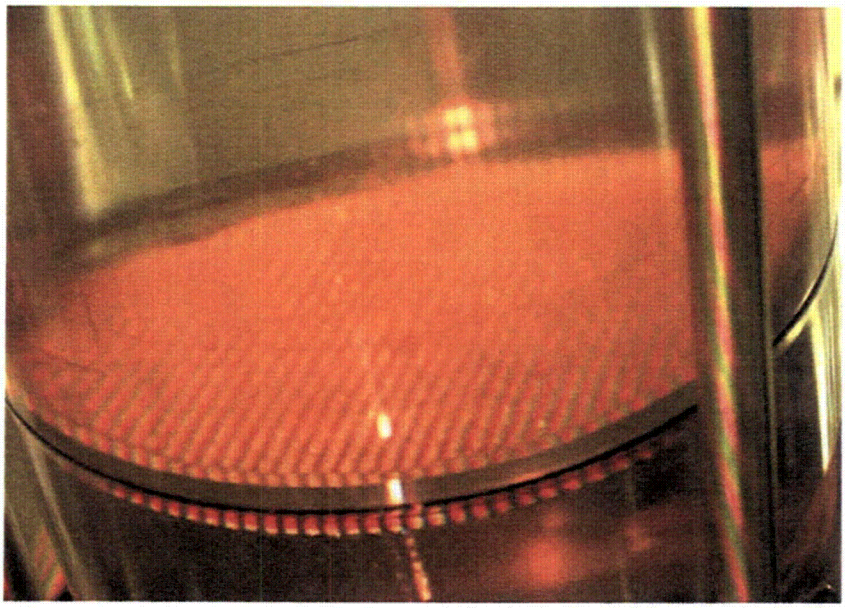


Figure J.6.4. 060517_NC_0808_LP1, LP2 Debris Bed in Test Section During Flow at for Final Test Velocity Phase. Grid lines are from optical triangulation light. Surface irregularities, holes, etc. of Figure J.6.3 are not observable. 11:00 orientation of debris bed in Figure J.41 corresponds to near-left-hand-side of Figure J.42 (note vertical black line on test section above debris bed at described orientation in each photo).

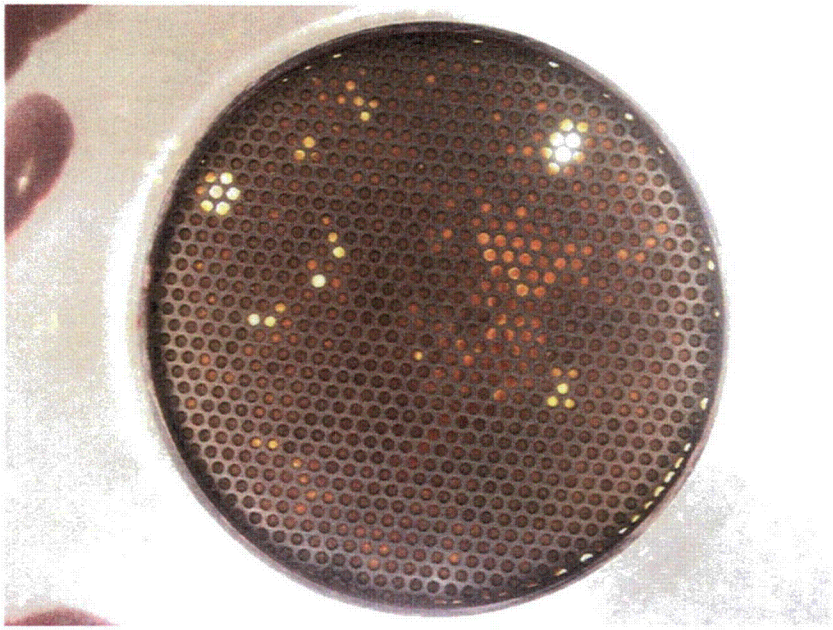


Figure J.6.5. 060517_NC_0808_LP1, LP2 Debris Bed in Test Section After Retrieval, Bottom View. Debris bed disturbed during retrieval (see Figure J.6.3). Some areas of light were visually observed to appear and disappear during testing (see text discussion).

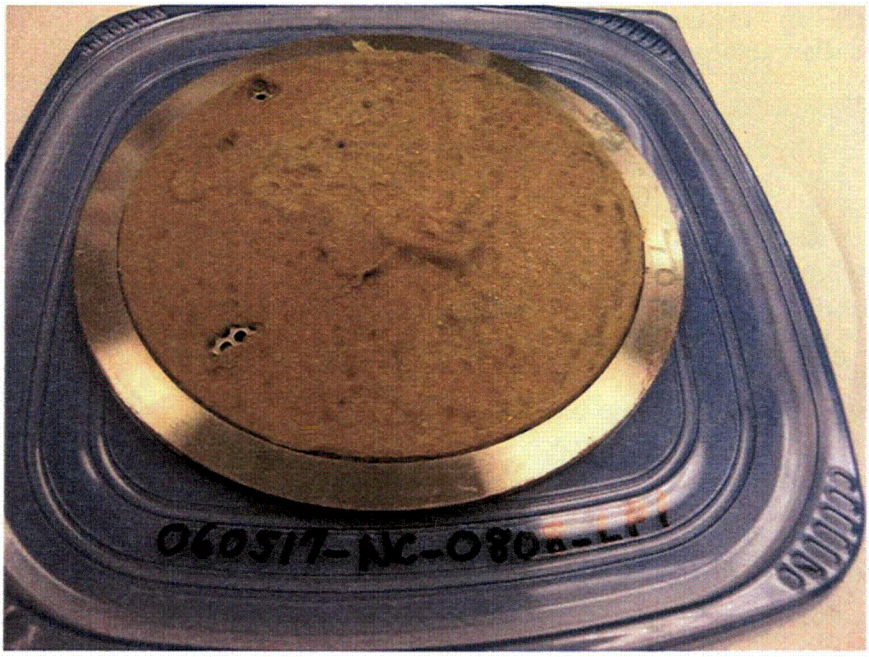


Figure J.6.6. 060517_NC_0808_LP1, LP2 Debris Bed After Retrieval from Test Section. Debris bed disturbed during retrieval (see Figure J.6.3 caption).

J.7 Quick-Look Report for PNNL Test 051121_NC_1586_L1, Test Condition LANL-6f Preliminary PNNL Head Loss Test Data

This report conveys preliminary data from the PNNL large-scale test loop Condition LANL-6f. No testing in the benchtop loop was performed at this condition. The debris bed was formed by attempting to maintain a constant velocity of 0.1 ft/sec. The pump frequency was increased as needed to compensate for the reduction in flow resulting from the increasing head loss across the developing debris bed.

PNNL has concerns regarding the NRC direction to reduce the approach velocity used to generate the debris beds from 0.2 to 0.1 ft/sec. The concern is that the reduced formation velocity results in material settling in the pipe system and being resuspended later as the velocity is incrementally ramped up. The goal was to eliminate mass addition throughout the rampup in velocity following testing performed to repeat the Los Alamos National Laboratory (LANL) test method (Figure J.7.2 compares PNNL and LANL data).

The addition of the filtering system is intended eliminate suspended material from the flow after bed formation and prior to increasing the flow. The increase in flow is anticipated to cause compaction, which will increase the material retention capability of the debris bed. However, filtering will be unable to remove settled material upstream of the debris bed.

The test results for the initial rampup in velocity plotted in Figure J.7.1 indicate that a significant amount of material may be resuspended for the corresponding flow rates resulting from approach velocities between 0.3 and 0.35 ft/sec. Similar results were observed in the results from test 051117_NC_ 2776_L1, which was also formed with an approach velocity maintained at 0.1 ft/sec.

All data are preliminary and were obtained from manual recordings taken from visual observation of the DAS screen readouts. In Table J.7.3, 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 rim whose height was measured 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 through the rim.

Test conditions are listed in Table J.7.1, preliminary data in Table J.7.2, and manual debris bed height measurements in Table J.7.4. 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 between approximately 0.06 and 0.08 in. below this datum, so 0.06 in. was added to the reported measurements. Measurements taken upon bed retrieval are provided in Table J.7.4. Figures J.7.3 through J.7.6 are photographs of the debris beds.

Table J.7.1. Test Conditions

Quick-Look Report date	11/22/05
Date of test	11/21/05
Associated test case(s)	LANL: 6f
Test number and data file reference	051121_NC_1586_L1
Target screen debris loading (g/m^2)	869.7
Initial NUKON mass introduced (g)	10.58
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	5.29
CalSil R4 target	1.5–1.9
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
Calculated number of representative circulations during debris bed formation (from estimated 8.5-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)	13.58

Table J.7.2. 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	0.1[b]	55	0.45	0.16	16
	0.1	63	0.47	-	17
	0.11	70	0.45	-	17
	0.15	99	0.43	-	17
	0.21	143	0.41	-	17
	0.25	184	0.39	-	18
	0.3	229	0.41	-	18
	0.35	317	0.39	-	18
	0.38	405	0.37	-	19
	0.43	524	0.37	-	21
Ramp down 1	0.4	488	0.41	-	21
	0.35	401	0.37	-	21
	0.3	320	0.37	-	21
	0.25	248	0.37	-	22
	0.2	185	0.37	-	22
	0.15	121	0.37	-	22
	0.1	71	0.37	-	22
Rampup 2	0.15	121	0.37	-	22
	0.2	185	0.37	-	22
	0.25	249	0.37	-	22
	0.3	337	0.37	-	22
	0.35	420	0.37	-	22
	0.39	495	0.37	-	23
	0.43	596	0.37	-	23

Table J.7.2 (contd.)

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim (in.)	Estimated Body[(a)] (in.)	
Ramp down 2	0.4	538	0.35	-	23
	0.35	445	0.37	-	24
	0.3	359	0.37	-	24
	0.25	281	0.37	-	24
	0.2	199	0.37	-	24
	0.15	132	0.39	-	24
	0.1	78	0.37	-	24
Rampup 3	0.15	132	0.37	-	24
	0.2	199	0.37	-	24
	0.25	281	0.37	-	24
	0.3	376	0.37	-	24
	0.35	467	0.37	0.20	24
	0.4	567	0.39	-	24
	0.43	653	0.37	-	25
Ramp down 3	0.4	589	0.37	-	25
	0.35	490	0.37	-	25
	0.3	399	0.39	-	26
	0.25	301	0.37	-	26
	0.2	216	0.35	-	26
	0.15	144	0.35	-	26
	0.1	78	0.37	-	26
Rampup 4	0.25	299	0.37	-	26
	0.42	659	0.37	-	26
Ramp down 4	0.25	301	0.35	-	26
	0.1	87	0.37	-	26
Rampup 5	0.43	685	0.33	-	27
Ramp down 5	0.4	619	0.33	-	27
	0.3	420	0.33	-	27
	0.2	230	0.35	-	27
	0.1	87	0.35	-	27
	0.05	33	0.33	-	27
	0.02	4	0.37	-	27
Rampup 6	0.1	80	0.35	-	26
	0.44	694	0.33	0.20	26
Ramp down 6	0.1	87	0.33	-	27

(a) 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 backlight showing through the rim. Blank (-) entries indicate that no distinct measurement was observed.
(b) Prior to increase of loop static pressure (~2.5 atm).

Table J.7.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.1	55	16	20
	0.1	63	17	20
	0.11	70	17	20
	0.15	99	17	20
	0.21	143	17	20
	0.25	184	18	20
	0.3	229	18	20
	0.35	317	18	20
	0.38	405	19	20
	0.43	524	21	20
Ramp down 1	0.4	488	21	20
	0.35	401	21	20
	0.3	320	21	20
	0.25	248	22	20
	0.2	185	22	20
	0.15	121	22	20
	0.1	71	22	20
Rampup 2	0.15	121	22	20
	0.2	185	22	20
	0.25	249	22	20
	0.3	337	22	20
	0.35	420	22	20
	0.39	495	23	20
	0.43	596	23	20
Ramp down 2	0.4	538	23	20
	0.35	445	24	20
	0.3	359	24	20
	0.25	281	24	20
	0.2	199	24	20
	0.15	132	24	20
	0.1	78	24	20
Rampup 3	0.15	132	24	20
	0.2	199	24	20
	0.25	281	24	20
	0.3	376	24	20
	0.35	467	24	20
	0.4	567	24	20
	0.43	653	25	20
Ramp down 3	0.4	589	25	20
	0.35	490	25	20
	0.3	399	26	20
	0.25	301	26	20
	0.2	216	26	20
	0.15	144	26	20
	0.1	78	26	20

Table J.7.3 (contd.)

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 4	0.25	299	26	20
	0.42	659	26	20
Ramp down 4	0.25	301	26	20
	0.1	87	26	20
Rampup 5	0.43	685	27	20
Ramp down 5	0.4	619	27	20
	0.3	420	27	20
	0.2	230	27	20
	0.1	87	27	20
	0.05	33	27	20
	0.02	4	27	20
Rampup 6	0.1	80	26	20
	0.44	694	26	20
Ramp down 6	0.1	87	27	20

Table J.7.4. Post-Retrieval Debris Bed Measurements

Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.36	0.12	6.06	5.59

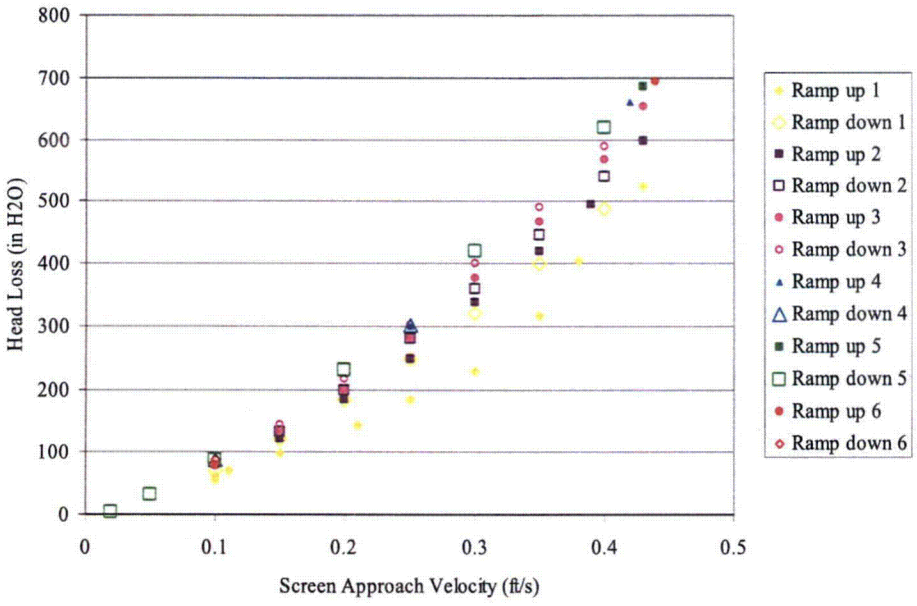


Figure J.7.1. Preliminary PNNL Data

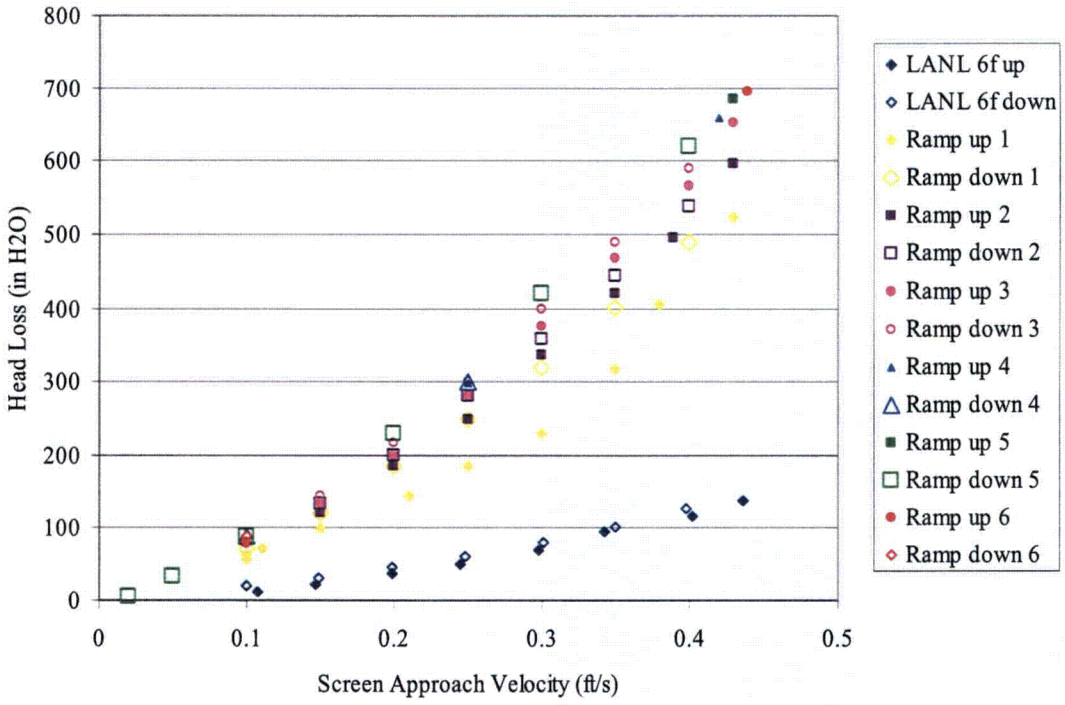


Figure J.7.2. Comparison of Preliminary PNNL Data and Previous Results (BT denotes PNNL benchtop)

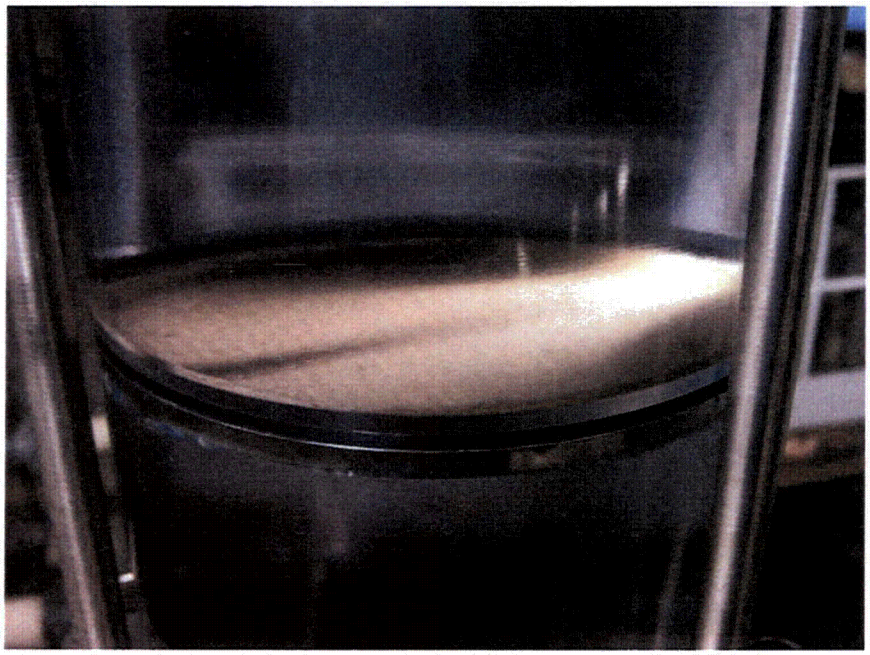


Figure J.7.3. Submerged 051121_NC_1586_L1 Debris Bed During Test. Screen pattern is observable on debris bed surface.

Figure J.7.4. 051121_NC_1586_L1 Debris Bed in Test Section After Retrieval, Top View. Screen pattern is observable on debris bed surface; dark pock-marks are from post-retrieval water drips.

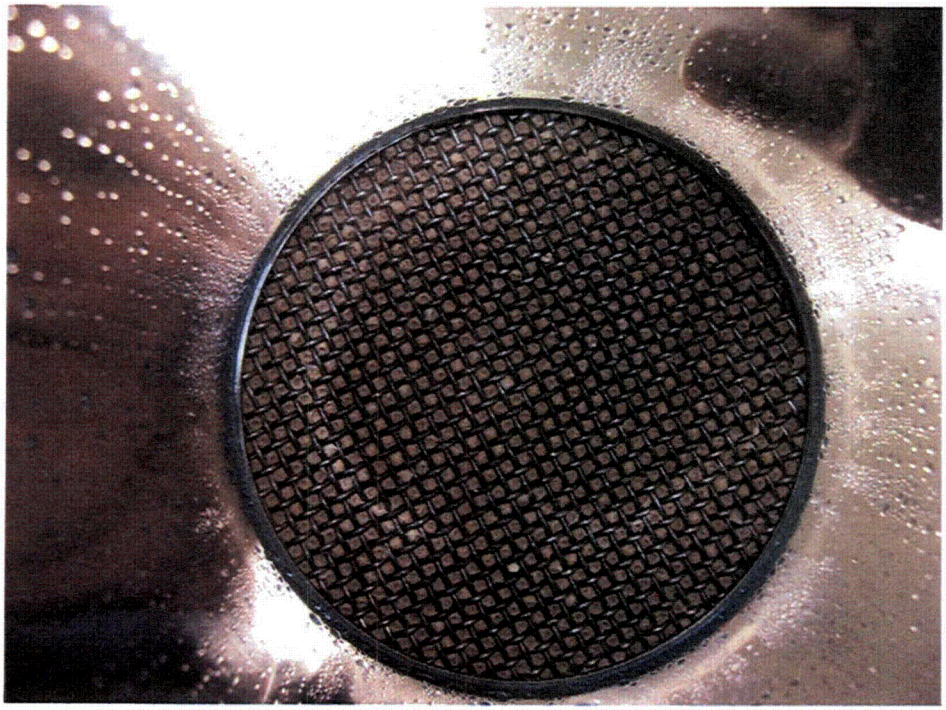


Figure J.7.5. 051121_NC_1586_L1 Debris Bed in Test Section After Retrieval, Bottom View

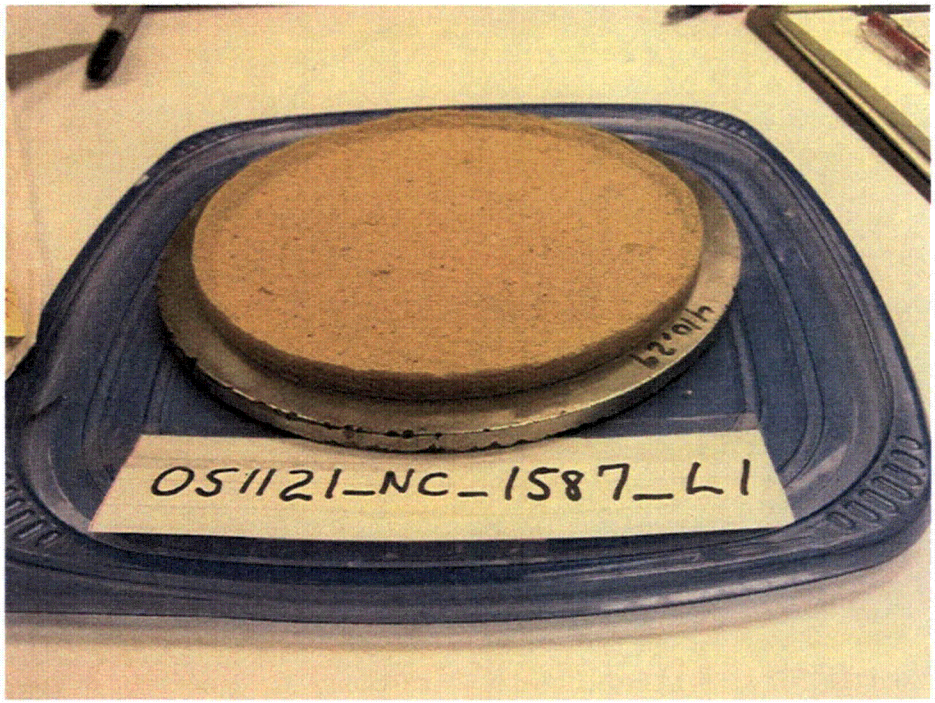


Figure J.7.6. 051121_NC_1586_L1 Debris Bed After Retrieval from Test Section. Screen pattern is observable on debris bed surface.

J.8 Quick-Look Report for PNNL Test 060323_NC_1619_LP1, Test Condition BM-3

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 DP meter with the most appropriate span for the given range of head loss readings. In Table J.8.3, 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 *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 ID 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 is observed through the rim. 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.

Test conditions are presented in Table J.8.1, and preliminary data are listed in Table J.8.2 and shown in Figure J.8.1. Manual debris bed height measurements are reported in Table J.8.4. 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 J.8.4. 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 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 J.8.5. 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. Figures J.8.2 – J.8.5 are photographs of the debris bed.

Table J.8.1. Test Conditions

Quick-Look Report Date	4/6/06
Date of test	3/23/06
Associated test case(s)	ANL BM-3
Test number and data file reference	060323_NC_1619_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)	869
Initial NUKON mass introduced (g)	13.49
NUKON R4 target and water dilution	16.4 for 1000 ml water dilution (for comparison, see *R4 pour tests, update3.14.06.doc*, ANL)
Initial CalSil mass introduced (g)	2.70
CalSil R4 target	N/A, prepared in accordance with *Preparation of NUKON and CalSil 3.03.06.doc*, ANL
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop
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)	12.04[(a)]
(a) Debris bed disturbed post-test during retrieval. Visual observation indicated negligible debris material loss due to the disturbance.	

Table J.8.2. 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[c] (in.)	
Bed Formation	0.10	11.2[c]	0.67	-	21
Ramp down 1	0.10	11.3[c]	0.65	-	21
Ramp down 1	0.05	5.5	0.65	-	21
Ramp down 1	0.02	2.0	0.65	-	21
Rampup 1	0.05	5.6	0.65	-	21
Rampup 1	0.10	11.8	0.62	-	21
Ramp down 2	0.05	5.7	0.62	-	21
Ramp down 2	0.02	1.9	0.62	-	22
Rampup 2	0.10	12.3	0.62	-	22
Rampup 2	0.15	18.9	0.60	-	22
Rampup 2	0.20	26.4	0.58	-	22
Ramp down 3	0.15	19.5	0.58	-	22
Ramp down 3	0.10	12.9	0.58	-	22
Rampup 3	0.15	20.4	0.58	-	22
Rampup 3	0.20	28.5	0.58	-	22
Ramp down 4	0.10	13.3	0.58	-	22
Ramp down 4	0.05	6.2	0.58	-	22
Ramp down 4	0.02	2.0	0.62	-	22
Rampup 4	0.10	13.3	0.60	-	22

(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) Pressure measurements taken prior to 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 off the screen at which there was a difference in the amount of backlighting showing through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.

Table J.8.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	11	21	23
Rampup 1	0.10	11	21	23
Rampup 1 (prefiltering)	0.20	6	21	23
Rampup 1 (post-filtering)	0.20	2	21	24
Ramp down 1	0.10	6	21	24
Ramp down 1	0.05	12	21	24
Ramp down 1	0.02	6	21	24
Rampup 2	0.10	2	22	24
Rampup 2	0.20	12	22	24
Ramp down 2	0.10	19	22	24
Ramp down 2	0.02	26	22	23
Rampup 3	0.10	20	22	23
Rampup 3	0.20	13	22	23
Ramp down 3	0.10	20	22	23
Ramp down 3	0.02	29	22	23
Rampup 4	0.10	13	22	23

Table J.8.4. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements[a]			
Rim Height (in)	**Body Height (in)**	**Total Bed Diameter (in)**	**Body Diameter (in)**
0.51	.21	6.06	N/A

(a) Post-retrieval debris bed disturbance precluded the ability to completely measure the surface elevation of the entire debris bed. Additionally, the measurements taken may reflect possible alterations in the debris bed height from the disturbance. See Photo 3 for observation and description of the disturbance.

Table J.8.5. 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**
060323_LP1_0.1_72_RD1	0.64	0.36	0.34	4.39	5.15	11.68
060323_LP1_0.02_74_RD1	0.59	0.36	0.34	4.44	5.26	11.29
060323_LP1_0.2_81_RU2	0.52	0.25	0.23	4.66	3.92	8.22
060323_LP1_0.1_89_RU4	0.52	0.25	0.23	4.57	3.78	8.31

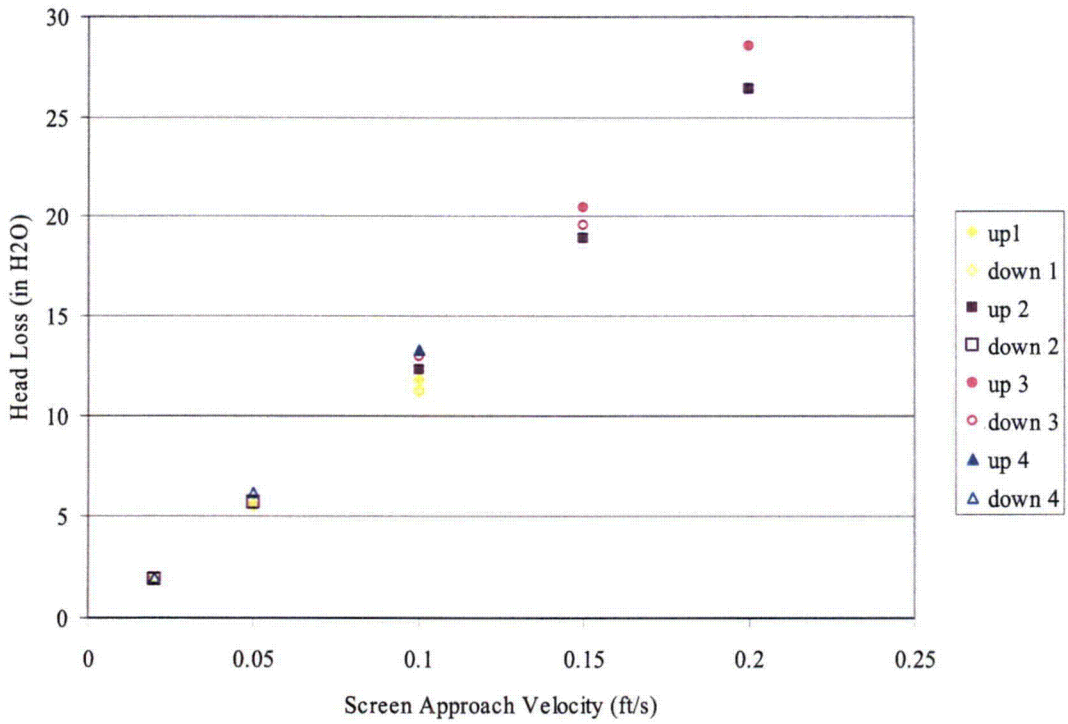


Figure J.8.1. Preliminary PNNL Data; 060323_NC_1619_LP1

Figure J.8.2. Submerged 060323_NC_1619_LP1 Debris Bed During Test

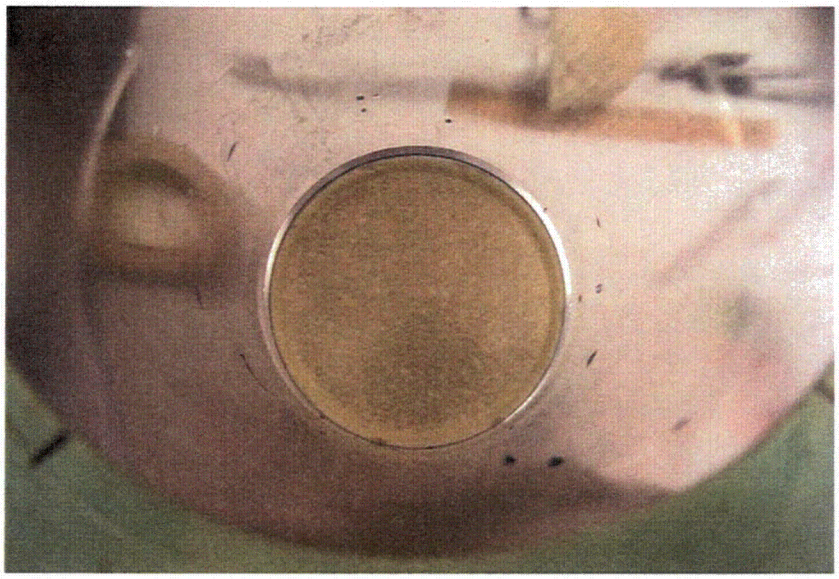


Figure J.8.3. 060323_NC_1619_LP1 Debris Bed in Test Section After Retrieval, Top View

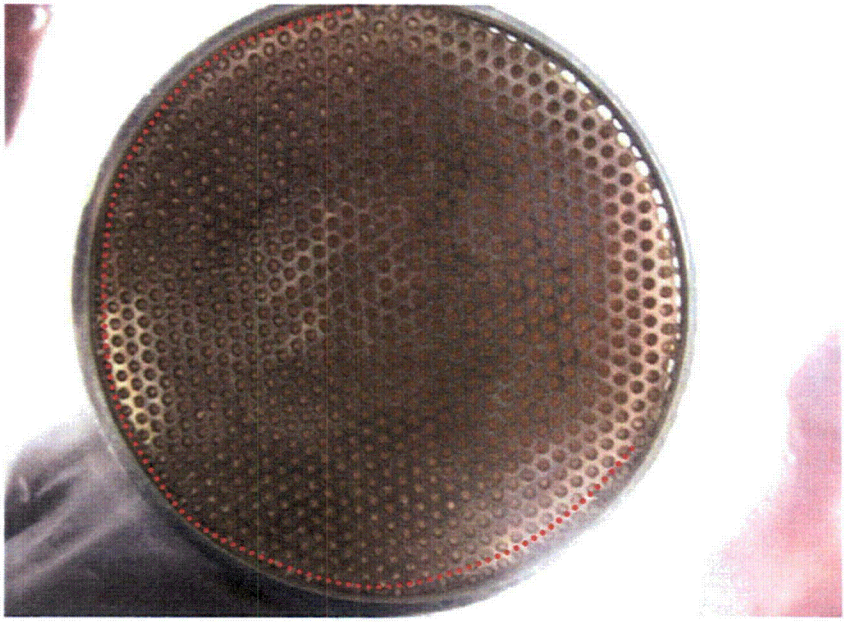


Figure J.8.4. 060323_NC_1619_LP1 Debris Bed in Test Section After Retrieval, Bottom View. (The post-test disturbance during retrieval is postulated to have resulted from unequal cover-gas pressure around the debris bed post-draining as retrieval was conducted. This issue will be rectified for subsequent tests. The postulated higher pressure under the debris bed resulted in an uplifting of a region of the debris bed. The region affected is visually observable by the open perforations from the 1:00 to 3:30 orientation at the debris bed edge. Roughly enclosed by the dashed red line is the area where the debris was visually observed to not protrude into the perforations of the plate. Refer to Quick Look Report BM-1, Photo 2, to observe evidence of how the debris material apparently protrudes into the perforations.)

Figure J.8.5. 060323_NC_1619_LP1 Debris Bed After Retrieval from Test Section

J.9 Quick-Look Report for PNNL Test 060331_NC_2024_LP1, Test Condition Series II Priority 4

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 DP meter with the most appropriate span for the given range of head loss readings. In Table J.9.3, 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 *060329 April test program memo.doc*. 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 bulk or "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 back-lighting, which shown through the rim, was observed. These measurements are referred to as "manual". Manual measurements of the debris-bed body are not always obtainable because a difference in back lightning is not always observed. In situ debris bed height measurements were also taken using optical triangulation.

Test conditions are presented in Table J.9.1, and preliminary data are listed in Table J.9.2 and shown in Figure J.9.1. Manual debris bed height measurements are reported in Table J.9.2. 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 J.9.4.

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 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 J.9.5. 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. Figures J.9.2 through J.9.5 are photographs of the debris beds.

Table J.9.1. Test Conditions

Quick-Look Report Date	4/7/06
Date of test	3/31/06
Associated test case(s)	Series II Priority 4
Test number and data file reference	060331_NC_2024_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)	1086
Initial NUKON mass introduced (g)	13.49
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	6.75
CalSil R4 target	< 1.55
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	76
Calculated number of representative circulations during debris bed formation (from estimated 11-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)	13.64

Table J.9.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim[c] (in.)	Estimated Body[d] (in.)	
Bed Formation	0.10	39[b]	0.38	-	21
Rampup 1	0.10	40	0.38	-	21
Rampup 1 (prefiltering)	0.20	120	0.36	-	22
Rampup 1 (post-filtering)	0.20	129	0.38	-	22
Ramp down 1	0.10	53	0.38	-	22
Ramp down 1	0.05	25	0.38	-	22
Ramp down 1	0.02	8	0.38	-	23
Rampup 2	0.10	52	0.38	-	23
Rampup 2	0.20	145	0.36	-	23
Ramp down 2	0.10	64	0.36	-	23
Ramp down 2	0.02	10	0.38	-	23
Rampup 3	0.10	60	0.38	-	23
Rampup 3	0.20	160	0.38	-	23
Ramp down 3	0.10	61	0.38	-	23
Ramp down 3	0.02	10	0.38	-	24
Rampup 4	0.10	68	0.38	-	24

(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) Pressure measurements taken prior to increase of loop static pressure (~2.5 atm).
(c) The debris bed rim height varied by up to approximately 0.1 in. in circumference.
(d) 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 backlighting observed through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.

Table J.9.3. Preliminary Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Bed Formation	0.10	39	21	23
Rampup 1	0.10	40	21	23
Rampup 1 (prefiltering)	0.20	120	22	23
Rampup 1 (post-filtering)	0.20	129	22	22
Ramp down 1	0.10	53	22	22
Ramp down 1	0.05	25	22	22
Ramp down 1	0.02	8	23	23
Rampup 2	0.10	52	23	23
Rampup 2	0.20	145	23	23
Ramp down 2	0.10	64	23	23
Ramp down 2	0.02	10	23	23
Rampup 3	0.10	60	23	23
Rampup 3	0.20	160	23	23
Ramp down 3	0.10	61	23	23
Ramp down 3	0.02	10	25	24
Rampup 4	0.10	68	24	24

Table J.9.4. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.33	0.15	6.06	5.43

Table J.9.5. 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
060331_LP1_0.1_98_RU1	0.40	0.18	0.16	4.61	2.67	5.99
060331_LP1_0.2_99_RU1nf	0.40	0.18	0.16	4.58	2.64	6.01
060331_LP1_0.02_03_RD1	0.42	0.26	0.24	4.78	4.30	7.78
060331_LP1_0.1_13_RU4	0.36	0.18	0.16	4.60	2.66	5.75

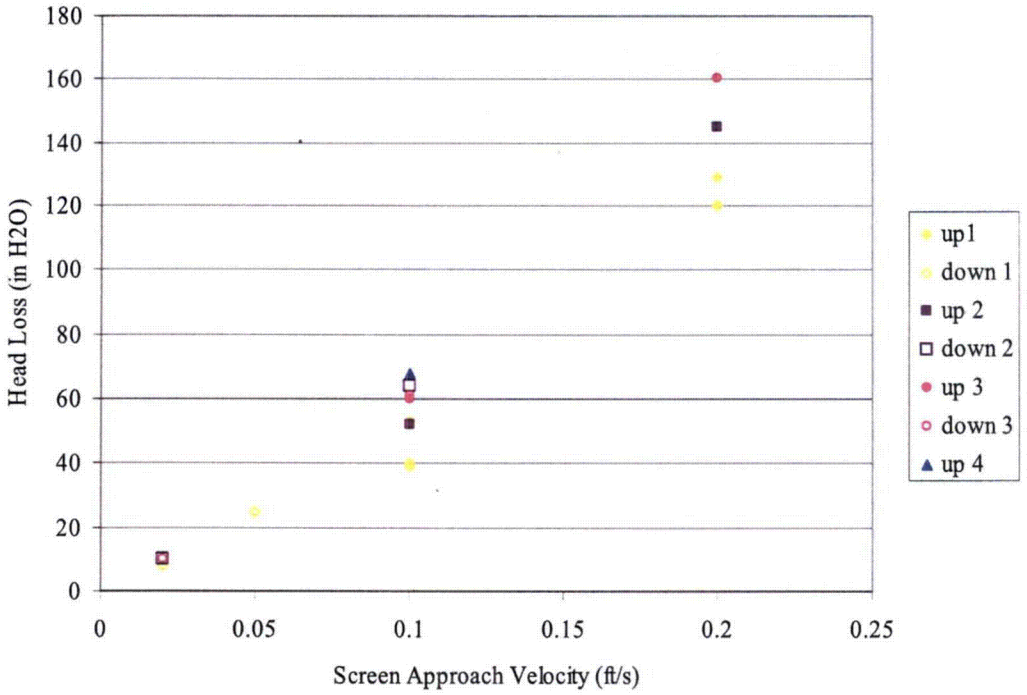


Figure J.9.1. Preliminary PNNL Data; 060331_NC_2024_LP1.

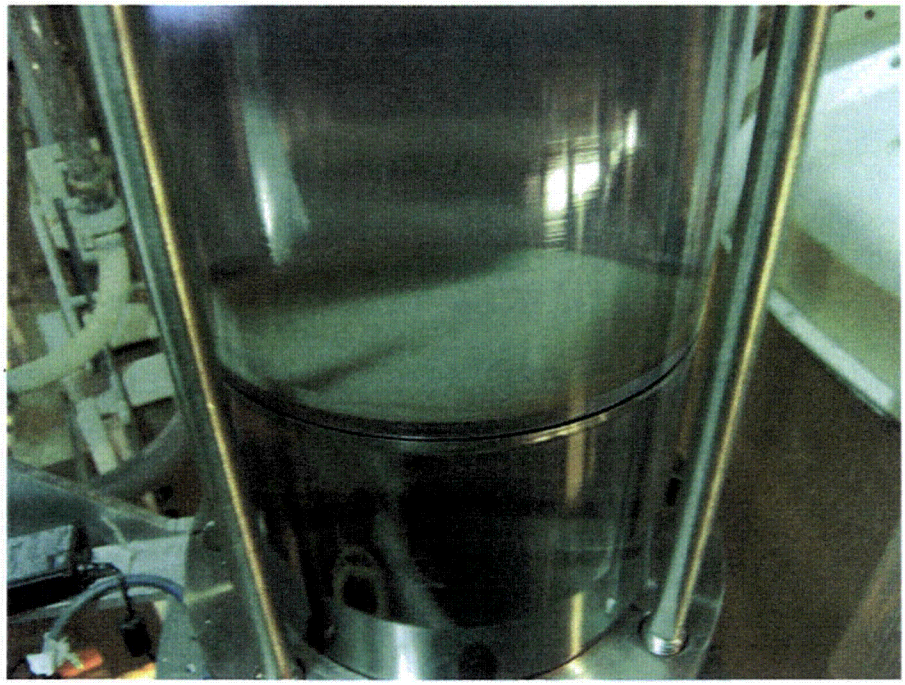


Figure J.9.2. Submerged 060331_NC_2024_LP1 Debris Bed During Test.

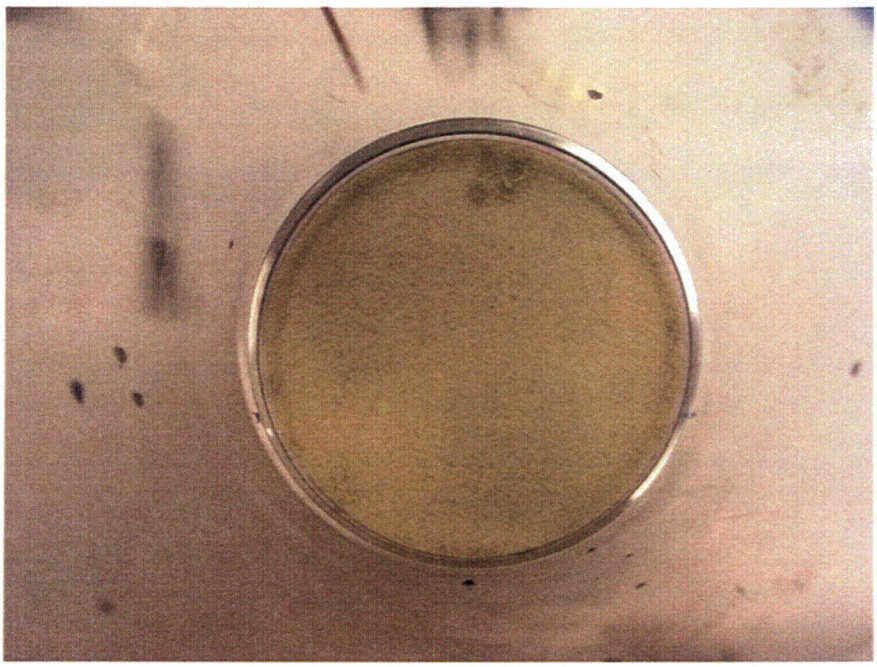


Figure J.9.3. 060331_NC_2024_LP1 Debris Bed in Test Section After Retrieval, Top View. Indentation at approximately 12:30 orientation was the result of water dripping during post-test retrieval.

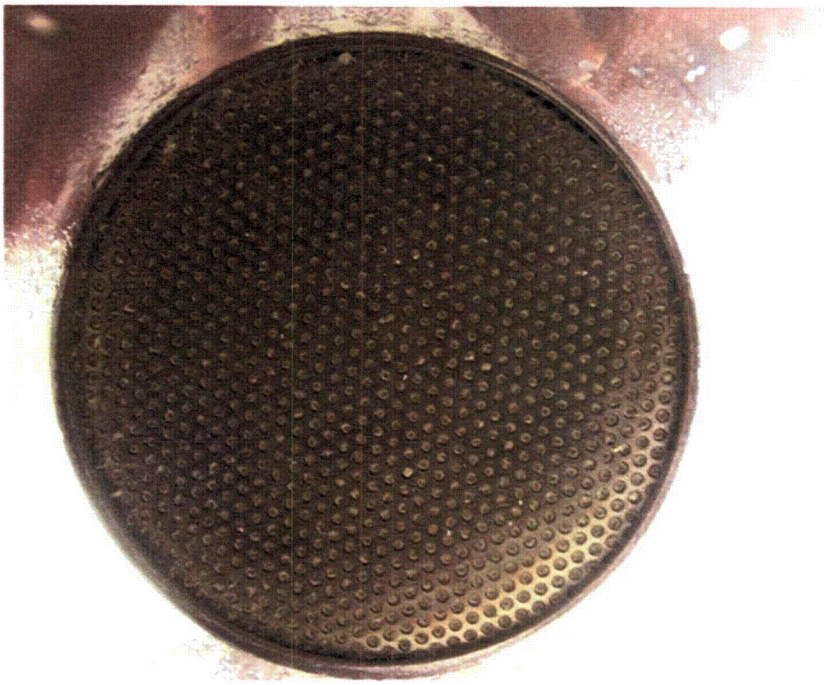


Figure J.9.4. 060331_NC_2024_LP1 Debris Bed in Test Section After Retrieval, Bottom View

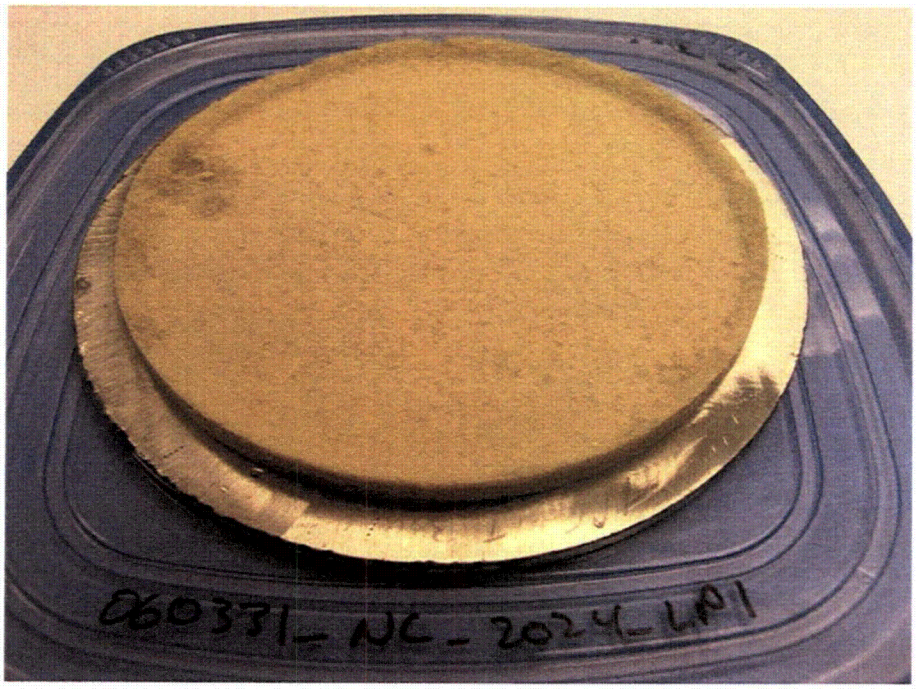


Figure J.9.5. 060331_NC_2024_LP1 Debris Bed After Retrieval from Test Section. Indentation at approximately 9:30 orientation is from water dripping during post-test retrieval.

J.10 Quick-Look Report for PNNL Test 060404_NC_2698_LP1, Test Condition Series II Priority 5 Head Loss Test Data

All data are preliminary and 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 Table J.10.3, 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 *060329 April test program memo.doc*. The test section inside diameter is 0.154 m (6.06 in.).

The debris bed had a raised rim whose height was measured directly 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 through the rim. These manual measurements 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.

Test conditions are listed in Table J..10.1and preliminary data are listed in Table J.10.2 and shown in Figure J.10.1. Manual debris bed height measurements are reported in Table J.10.2. The top of the

Table J.10.1. Test Conditions

Quick-Look Report date	4/10/06
Date of test	4/4/06
Associated test case(s)	Series II Priority 5
Test number and data file reference	060404_NC_2698_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)	1448
Initial NUKON mass introduced (g)	13.49
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	13.49
CalSil R4 target	< 1.55
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	N/A[(a)]
Bed formation time (min)	N/A[(a)]
Calculated number of representative circulations during debris bed formation (from estimated 11-min circulation time)	N/A[(a)]
Target static pressure increase[(b)] (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[(c)] (g)	16.07

(a) After the second circulation of the debris cloud through the test loop and onto/past the perforated plate, the head loss at nominally 0.01 ft/sec reached the maximum value of the highest spanned DP meter, 750 in. H_2O approximately 12 min after the debris was introduced. The maximum DP span setting and instructions to not exceed 450 in. H_2O pressure drop precluded increasing the velocity to the bed formation specification of 0.1 ft/sec. Thus the *060329 April test program memo.doc* bed formation time of 1 hr at 0.1 ft/sec was not met. The test was conducted for about 100 minutes, about 12 min at 0.1 ft/sec and 88 min at 0.01 ft/sec, resulting in a calculated number of representative circulations of approximately 2.3.
(b) The significant head loss of the debris bed and required accelerated pump speed after the second circulation resulted in a gas pocket below the debris bed. The static loop pressure was increased about 20 min into the test to eliminate the gas pocket.
(c) Debris bed was disturbed post-retrieval. Unquantifiable debris mass may have been lost.

Table J.10.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim[c] (in.)	Estimated Body[d] (in.)	
After First Debris Cloud Pass	0.10	71[b]	-	-	19
End of Test	0.008	749	0.42	-	24
Bed Formation	0.10	N/A[e]			
Rampup 1	0.10				
Rampup 1 (prefiltering)	0.20				
Rampup 1 (post-filtering)	0.20				
Ramp down 1	0.10				
Ramp down 1	0.05				
Ramp down 1	0.02				
Rampup 2	0.10				
Rampup 2	0.20				
Ramp down 2	0.10				
Ramp down 2	0.02				
Rampup 3	0.10				
Rampup 3	0.20				
Ramp down 3	0.10				
Ramp down 3	0.02				
Rampup 4	0.10				

(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) Pressure measurements taken prior to increase of loop static pressure (~2.5 atm).
(c) The debris bed rim height varied by up to approximately 0.1 in. circumferentially.
(d) The estimated body height of the debris bed was taken during testing by visually observing and recording the elevation off the screen at which a difference in backlighting was observed through the rim. Blank (--) entries indicate that no measurement was taken because no difference in backlighting was observed.
(e) See footnote (a) of Table J.10.1. Test was terminated at approximately 100 minutes per personal communication from WJ Krotiuk to CW Enderlin (subsequently to BE Wells ~11:45 AM PST, 4/4/06). No velocity cycles were performed, and no during-test filtering (see 060329 April test program memo.doc) was conducted.

Table J.10.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
After 1st Debris Cloud Pass	0.10	71	19	20
End of Test	0.008	748	24	20
Bed Formation	0.10			

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, so 0.0625 in. was added to the reported measurements.

Post-retrieval debris bed height measurements taken upon bed retrieval are provided in Table J.10.4. 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 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 J.10.5. 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. Figures J.10.2 through J.10.5 are photographs of the debris bed.

Table J.10.4. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements[a]			
Rim Height (in.)	**Body Height (in.)**	**Total Bed Diameter (in.)**	**Body Diameter (in.)**
0.39	0.23	6.06	N/A

(a) Debris bed disturbed post-test during retrieval. The reported measurements may reflect alterations in debris bed height from the disturbance. See Figure J.10.4 for a description of the disturbance. Rim height was determined with ruler placed vertically next to debris bed rim, and body height was determined with a caliper on debris bed regions not visually observed to be altered by disturbance.

Table J.10.5. 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**
060404_LP1_0.1_16_DP1_noSS	0.44	0.22	0.20	4.52	3.21	7.32
060404_LP1_0.008_19_BFplus	0.40	0.17	0.16	4.72	2.80	5.99

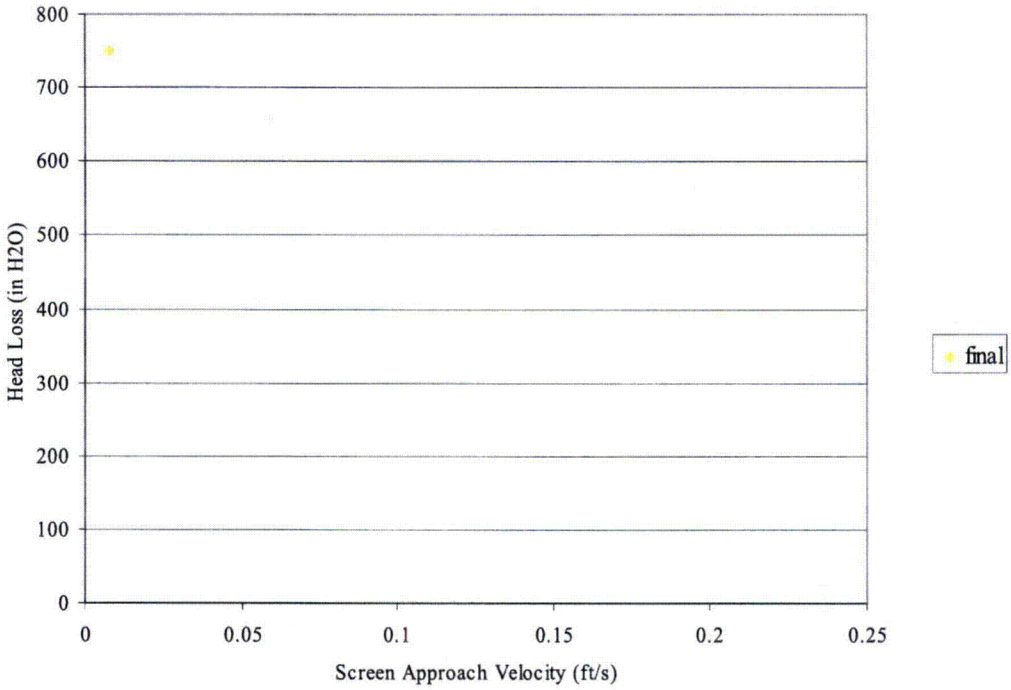


Figure J.10.1. Preliminary PNNL Data; 060404_NC_2698_LP1

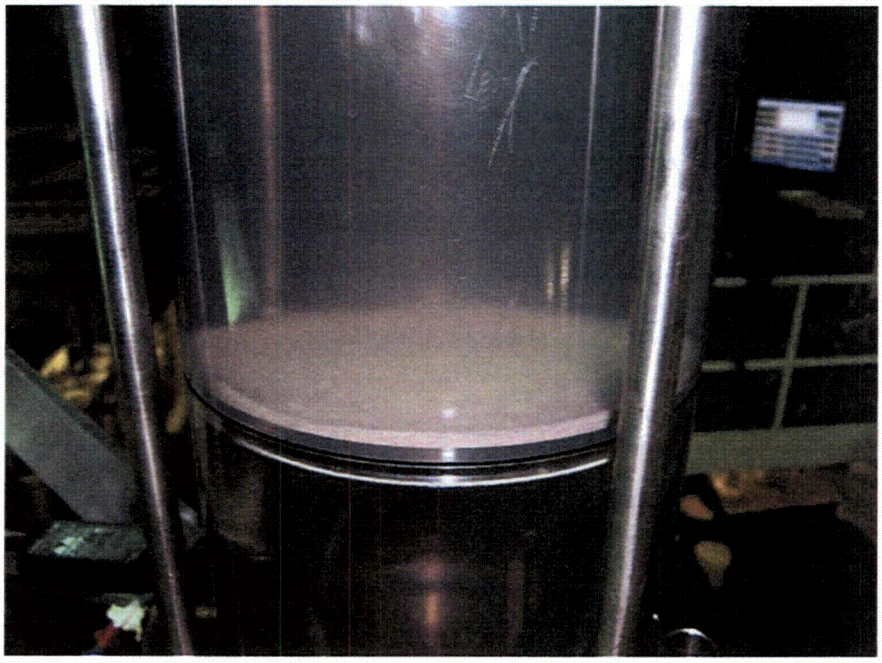


Figure J.10.2. Submerged 060404_NC_2698_LP1 Debris Bed During Test

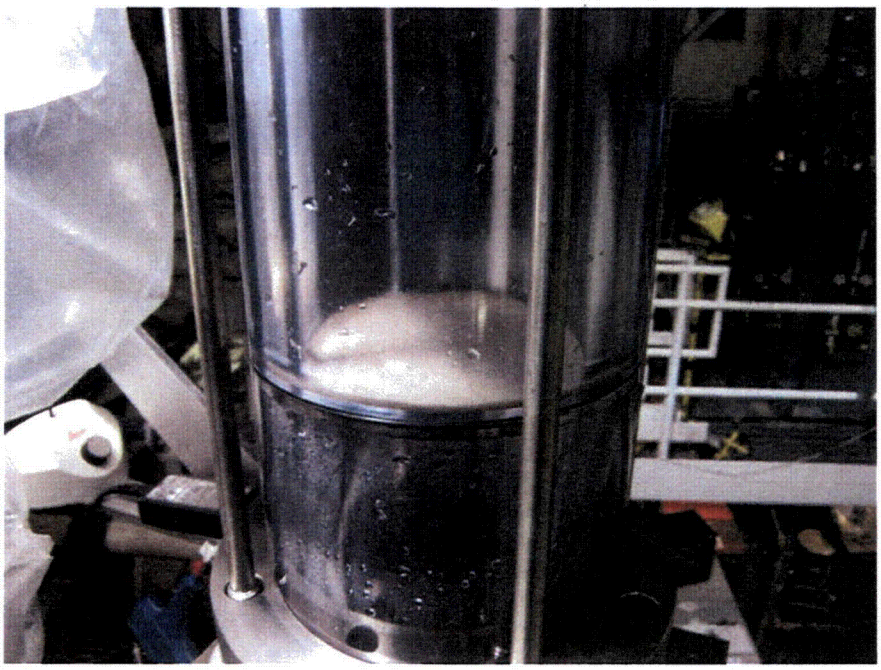


Figure J.10.3. Submerged 060404_NC_2698_LP1 Debris Bed During Test

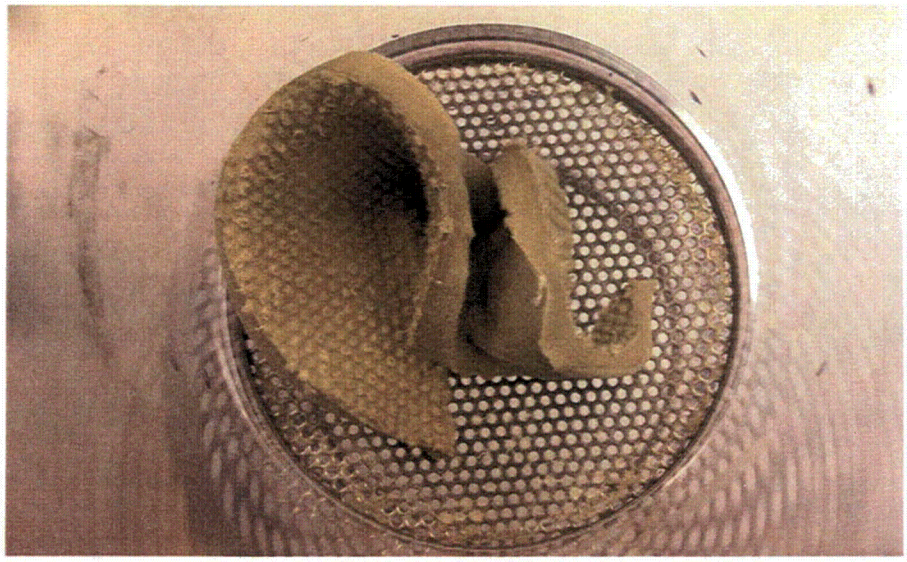


Figure J.10.4. 060404_NC_2698_LP1 Debris Bed in Test Section After Retrieval, Top View. The disturbance resulted from unequal cover-gas pressure around the debris bed post-draining. After test BM-3, a vent was added below the debris bed to allow the test loop to be drained and gas pressure equalized without rupture (Figure J.10.3), even with the relative impermeability of the debris bed. The impermeability resulted in water being held above and an air void below. While removing the water, a portion of the test loop below the debris bed was isolated while under pressure. Subsequent opening of this portion of the test loop before removing the debris bed resulted in the rupture. Test procedures will be modified to prevent reoccurrence.

Figure J.10.5. 060404_NC_2698_LP1 Debris Bed After Retrieval from Test Section (laid flat after rupture of Figure J.29)

J.11 Quick-Look Report 6i Preliminary PNNL Head Loss Test Data

All data are preliminary and were obtained from manual recordings of visual observation of the DAS readouts. In Table J.11.3, 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 rim whose height 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 through the rim.

Test conditions are presented in Table J.11.1,and preliminary data are listed in Table J.11.2 and shown in Figure J.11.1. Manual debris bed height measurements are reported in Table J.11.2. 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 between approximately 0.06 and 0.08 in. below this datum. Therefore, 0.06 in. has been added to the reported measurements. Post-retrieval debris bed measurements taken upon bed retrieval are provided in Table J.11.4. Figures J.11.3 through J.11.8 are photographs of the debris bed.

Table J.11.1. Test Conditions

Quick-Look Report date	11/29/05
Date of test	11/23/05
Associated test case(s)	LANL: 6i
Test number and data file reference	051123_NC_2181_L1
Target screen debris loading (g/m^2)	1195.8
Initial NUKON mass introduced (g)	14.54
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	7.27
CalSil R4 target	1.5–1.9
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
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)	19.28

Table J.11.2. Preliminary Data

Test Phase	Velocity (ft/sec)	Head Loss (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim (in.)	Estimated Body[(b)] (in.)	
Rampup 1	0.1(a)	64	0.59	-	22
	0.1	63	0.61	-	22
	0.15	110	0.57	-	22
	0.18	164	0.53	-	22
	0.21	243	0.55	-	23
	0.23	421	0.51	-	23
	0.25	730	0.51	0.28	27
Ramp down 1	0.15	495	0.41	-	32
	0.1	240	0.43	-	32
Rampup 2	0.15	473	0.41	-	32
	0.19	735	0.41	-	32
Ramp down 2	0.15	515	0.41	-	32
	0.12	374	0.41	-	31
	0.1	287	0.41	-	31
Rampup 3	0.12	373	0.41	-	31
	0.14	518	0.39	-	31
	0.18	737	0.41	-	31
Ramp down 3	0.15	540	0.39	-	31
	0.12	394	0.41	-	31
	0.1	286	0.41	0.18	31
	0.05	94	0.41	0.18	31
	0.02	25	0.41	0.18	30
Rampup 4	0.1	246	0.41	-	30
	0.18	693	0.41	-	30
	0.19	747	0.41	-	30
Ramp down 4	0.1	278	0.41	0.16	30

(a) Prior to increase of loop static pressure (~2.5 atm).

(b) The body height of the debris bed was estimated during testing by visually observing and recording the elevation off the screen at which a difference in backlight was observed through the rim. Blank (--) entries indicate that no distinct difference was observed. Measurements taken upon bed retrieval are provided in Table J.11.4.

Table J.11.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.1	64	22	20
	0.1	63	22	20
	0.15	110	22	20
	0.18	164	22	20
	0.21	243	23	20
	0.23	421	23	20
	0.25	730	27	20
Ramp down 1	0.15	495	32	20
	0.1	240	32	20
Rampup 2	0.15	473	32	20
	0.19	735	32	20
Ramp down 2	0.15	515	32	20
	0.12	374	31	20
	0.1	287	31	20
Rampup 3	0.12	373	31	20
	0.14	518	31	20
	0.18	737	31	20
Ramp down 3	0.15	540	31	20
	0.12	394	31	20
	0.1	286	31	20
	0.05	94	31	20
	0.02	25	30	20
Rampup 4	0.1	246	30	20
	0.18	693	30	20
	0.19	747	30	20
Ramp down 4	0.1	278	30	20

Table J.11.4. Post-Retrieval Debris Bed Measurements

Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.35	0.12	6.06	5.65

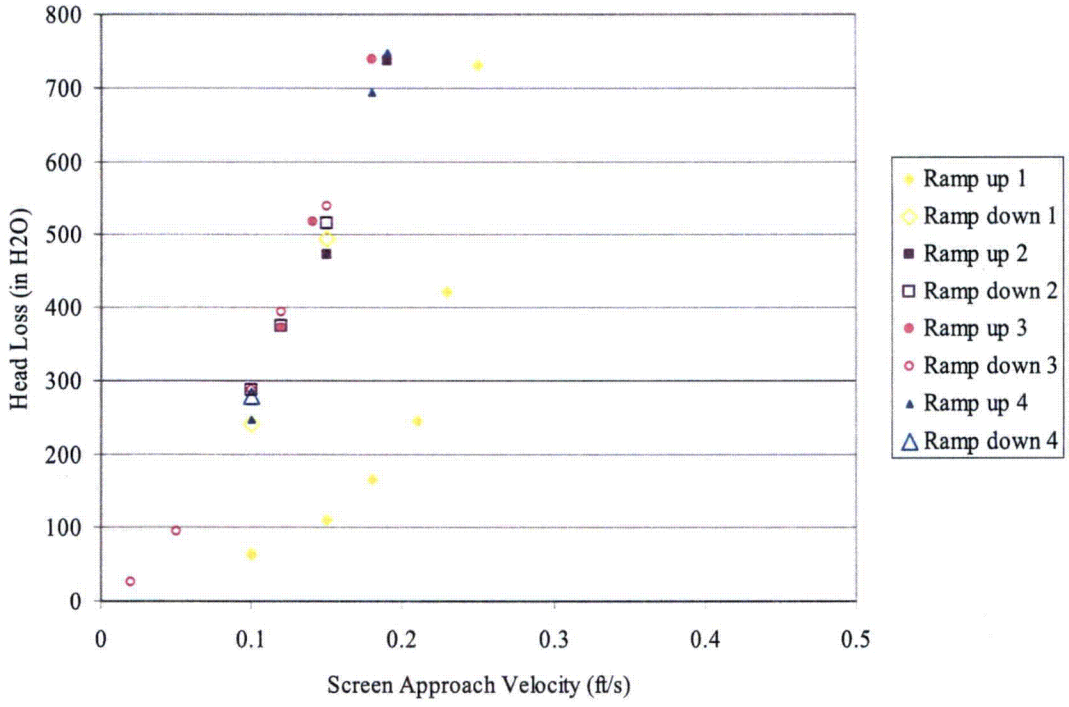


Figure J.11.1. Preliminary PNNL Data

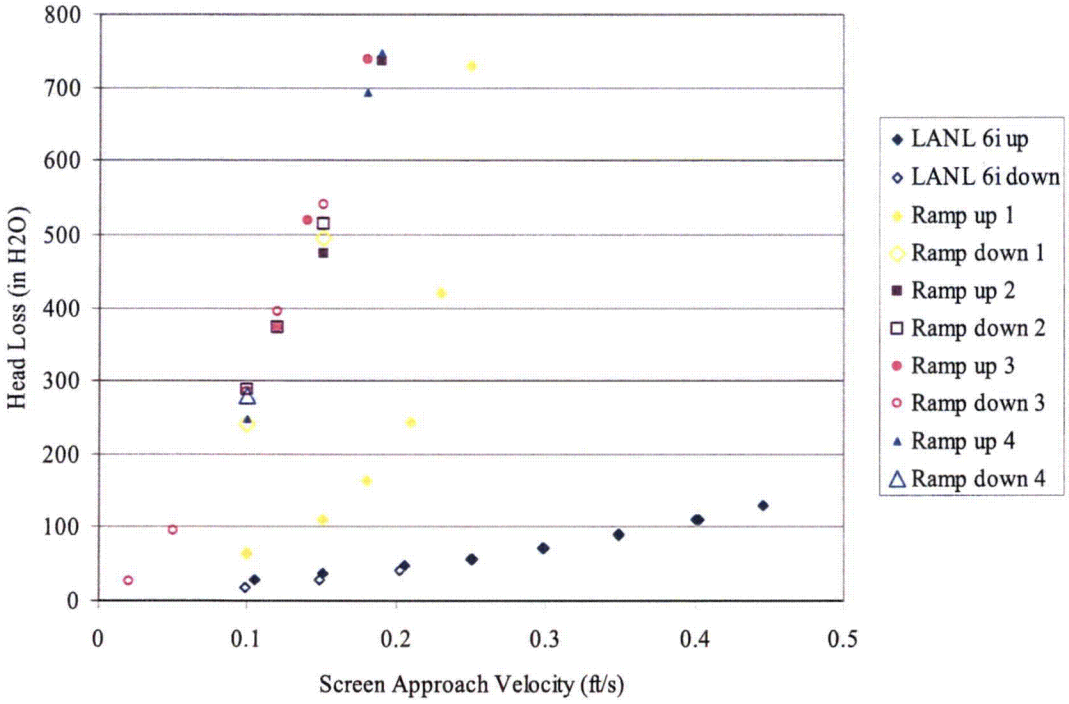


Figure J.11.2. Comparison of Preliminary PNNL Data and Previous Results (BT denotes PNNL benchtop)

Figure J.11.3. Submerged 051123_NC_2181_L1 Debris Bed During Test. Screen pattern is observable on debris bed surface; flow channel is observable in foreground.

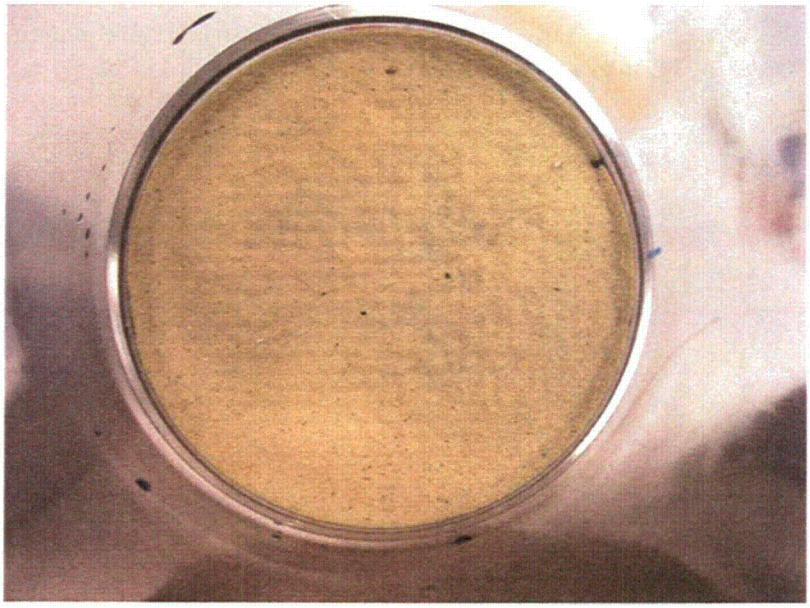


Figure J.11.4. 051123_NC_2181_L1 Debris Bed in Test Section After Retrieval, Top View. Screen pattern is observable on debris bed surface; flow channels are observable at 2:15 and 3:30 orientations.

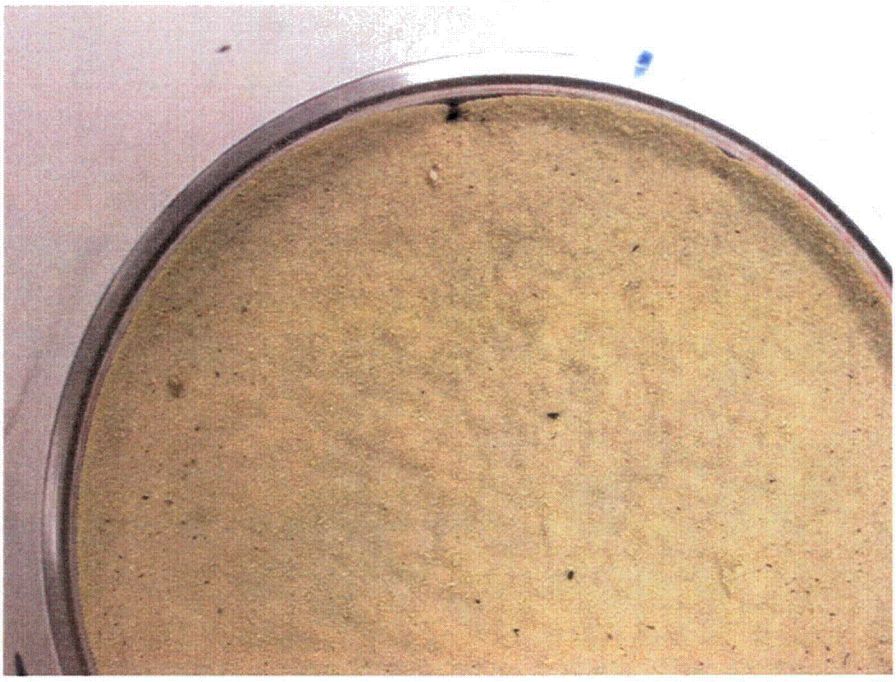


Figure J.11.5. Close-Up of 051123_NC_2181_L1 Debris Bed in Test Section After Retrieval, Top View. Screen pattern is observable on debris bed surface; flow channels are observable at 11:45 and 1:30 orientations.

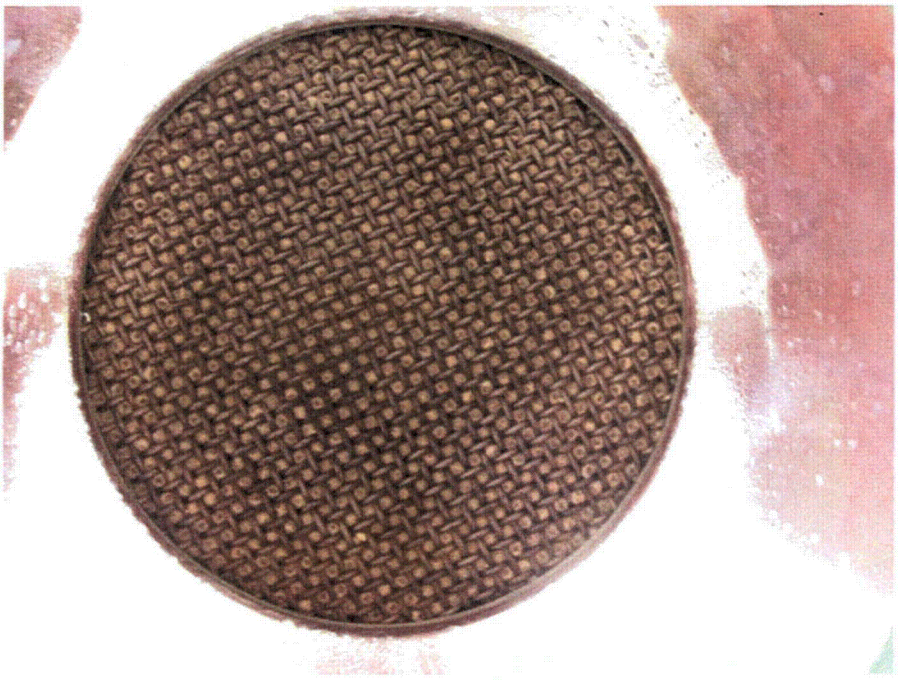


Figure J.11.6. 051123_NC_2181_L1 Debris Bed in Test Section After Retrieval, Bottom View. Flow channel hole is observable at 9:00 orientation.

Figure J.11.7. 051123_NC_2181_L1 Debris Bed After Retrieval from Test Section. Screen pattern is observable on debris bed surface; flow channels are observable on left side of debris bed.

Figure J.11.8. Close-up of 051123_NC_2181_L1 Debris Bed After Retrieval from Test Section. Screen pattern is observable on debris bed surface; flow channels are observable on debris bed edge.

J.12 Quick-Look Report for PNNL Test 051117_NC_2776_L1, Test Condition LANL-6e Preliminary PNNL Head Loss Test Data

This Quick-Look report conveys preliminary data from the PNNL large-scale test loop Test Condition LANL-6e. No testing in the PNNL benchtop loop has been performed at this condition.

The debris bed was formed by attempting to maintain a constant velocity of 0.1 ft/sec. The pump frequency was increased as needed to compensate for the reduction in flow resulting from the increasing head loss across the developing debris bed.

Before conducting Test 051117_NC2776_L1, loop components were disconnected to inspect for deposits of debris material in the lines. No deposits were observed in the bottom of the piping or hoses. Very small amounts of CalSil were observed deposited on gaskets.

All data are preliminary and were obtained from manual recordings taken from visual observation of the DAS screen readouts. In Table J.12.3, 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. The test section inside diameter is 0.154 m (6.06 in.).

The debris beds formed typically had a rim that was thicker than the body of the debris bed. 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 through the rim.

Test conditions are listed in Table J.12.1 and manual debris bed height measurements in Table J.12.2. Preliminary data are listed in Table J.12.2 and shown in Figure J.12.1. Figure J.12.2 compares PNNL data with previous tests. The top of the screen assembly support ring was used as the reference datum to

Table J.12.1. Test Conditions

Quick-Look Report date	11/21/05
Date of test	11/17/05
Associated test case(s)	LANL: 6e
Test number and data file reference	051117_NC_2776_L1
Target screen debris loading (g/m^2)	1522
Initial NUKON mass introduced (g)	18.51
NUKON R4 target	10–12
Initial CalSil mass introduced (g)	9.25
CalSil R4 target	1.5–1.9
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
Calculated number of representative circulations during debris bed formation (from estimated 8.5 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)	24.87

Table J.12.2. 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	0.1[b]	48	0.65	0.33	21
	0.1	55	0.63	0.33	21
	0.16	99	0.59	0.31	22
	0.2	136	0.57	-	22
	0.25	191	0.53	-	23
	0.3	271	0.57	-	23
	0.35	346	0.55	0.30	23
	0.4	525	0.53	-	24
Ramp down 1	0.35	433	0.53	-	24
	0.3	365	0.53	-	24
	0.25	286	0.53	-	25
	0.2	204	0.53	-	25
	0.15	145	0.53	-	25
	0.1	78	0.53	-	25
Rampup 2	0.15	134	0.55	-	25
	0.2	203	0.55	-	25
	0.25	287	0.53	-	25
	0.3	366	0.53	-	25
	0.35	477	0.51	-	25
	0.39	580	0.51	-	25
Ramp down 2	0.35	500	0.51	-	25
	0.3	406	0.51	-	26
	0.25	322	0.53	-	26
	0.2	233	0.53	-	26
	0.15	158	0.51	-	25
	0.1	97	0.51	-	25
Rampup 3	0.15	158	0.53	-	25
	0.2	234	0.53	-	25
	0.25	321	0.53	-	25
	0.3	427	0.51	-	25
	0.35	524	0.51	-	25
	0.4	659	0.53	-	25
Ramp down 3	0.35	571	0.49	-	26
	0.3	449	0.49	-	26
	0.25	359	0.49	-	26
	0.2	263	0.49	-	26
	0.15	170	0.53	-	26
	0.1	97	0.53	-	26
Rampup 4	0.25	341	0.51	-	26
	0.4	688	0.49	-	27
Ramp down 4	0.25	361	0.51	-	27
	0.1	107	0.51	-	27
Rampup 5	0.39	716	0.45	-	27
Ramp down 5	0.3	494	0.49	-	27
	0.2	281	0.49	-	27
	0.1	107	0.49	-	27
	0.05	45	0.49	-	27
	0.02	6	0.53	-	27
Rampup 6	0.1	97	0.53	-	27
	0.4	826	N/A	-	27
Ramp down 6	0.1	128	0.41	-	27

(a) 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 distinct measurement was observed.
(b) Prior to increase of loop static pressure (~2.5 atm).

Table J.12.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.1	48	21	20
	0.1	55	21	20
	0.16	99	22	20
	0.2	136	22	20
	0.25	191	23	20
	0.3	271	23	20
	0.35	346	23	20
	0.4	525	24	20
Ramp down 1	0.35	433	24	20
	0.3	365	24	20
	0.25	286	25	20
	0.2	204	25	20
	0.15	145	25	20
	0.1	78	25	20
Rampup 2	0.15	134	25	20
	0.2	203	25	20
	0.25	287	25	20
	0.3	366	25	20
	0.35	477	25	20
	0.39	580	25	20
Ramp down 2	0.35	500	25	20
	0.3	406	26	20
	0.25	322	26	20
	0.2	233	26	20
	0.15	158	25	20
	0.1	97	25	20
Rampup 3	0.15	158	25	20
	0.2	234	25	20
	0.25	321	25	20
	0.3	427	25	20
	0.35	524	25	20
	0.4	659	25	20
Ramp down 3	0.35	571	26	20
	0.3	449	26	20
	0.25	359	26	20
	0.2	263	26	20
	0.15	170	26	20
	0.1	97	26	20
Rampup 4	0.25	341	26	20
	0.4	688	27	20
Ramp down 4	0.25	361	27	20
	0.1	107	27	20
Rampup 5	0.39	716	27	20
Ramp down 5	0.3	494	27	20
	0.2	281	27	20
	0.1	107	27	20
	0.05	45	27	20
	0.02	6	27	20
Rampup 6	0.1	97	27	20
	0.4	826	27	20
Ramp down 6	0.1	128	27	20

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; thus, 0.06 in. was added to reported measurements. Measurements taken at bed retrieval are provided in Table J.12.4.

Table J.12.4. Post Retrieval Debris Bed Measurements

Manual Debris Bed Measurements			
Rim Height (in.)	**Body Height (in.)**	**Total Bed Diameter (in.)**	**Body Diameter (in.)**
0.47	0.24	6.06	5.61

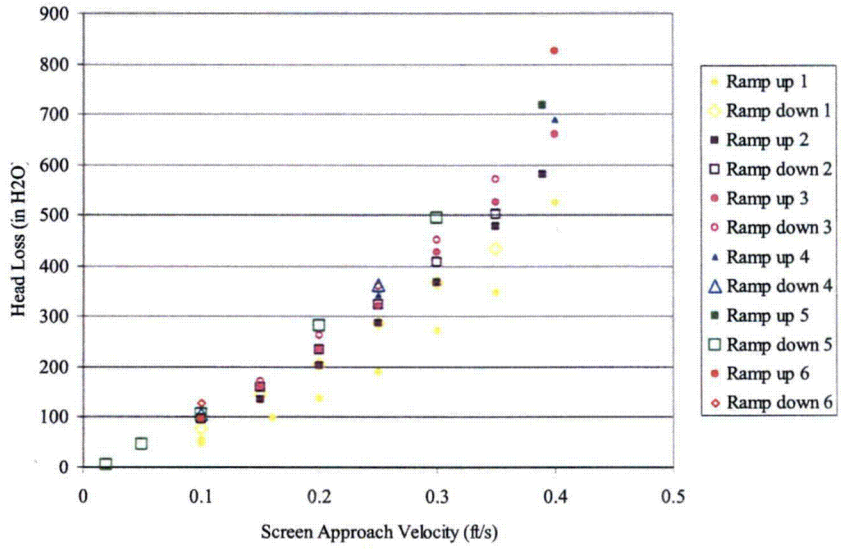


Figure J.12.1. Preliminary PNNL Data

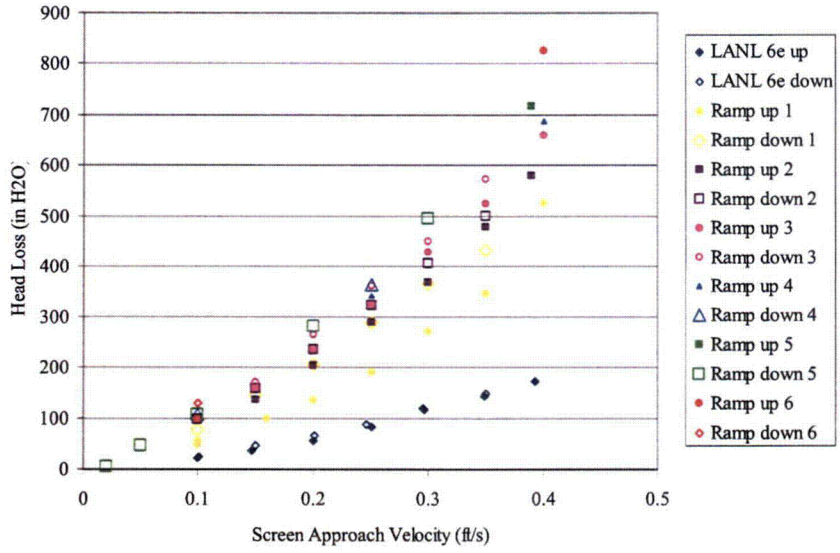


Figure J.12.2. Comparison of Preliminary PNNL Data and Previous Results (BT=PNNL benchtop)

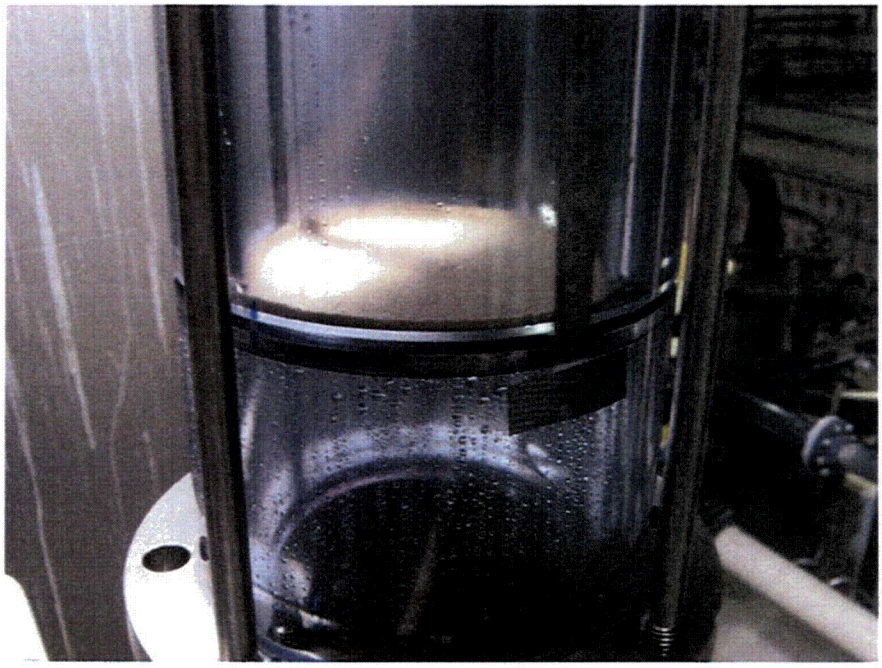


Figure J.12.3. 051117_NC_2776_L1 Debris Bed After Draining Loop

Figure J.12.4. 051117_NC_2776_L1 Debris Bed in Test Section After Retrieval, Top View. Screen pattern is observable on debris bed surface.

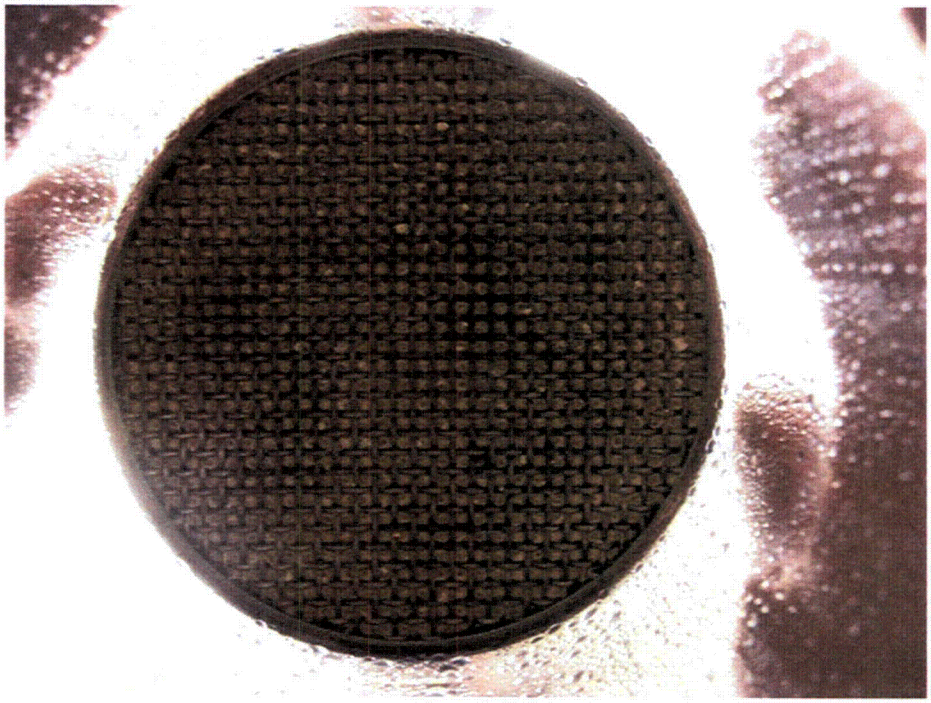


Figure J.12.5. 051117_NC_2776_L1 Debris Bed in Test Section After Retrieval, Bottom View

Figure J.12.6. 051117_NC_2776_L1 Debris Bed After Retrieval from Test Section. Screen pattern is observable on debris bed surface.

J.13 Quick-Look Report 6e2 – Preliminary PNNL Head Loss Test Data

All data contained herein is preliminary. The data was obtained from manual recordings taken from visual observation of the DAS screen readouts. In Table J.13.3, 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 listed in Table J.13.2. 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 rim of material against the wall of the test section that was thicker than the body of the debris bed. 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 through the rim.

Test conditions are presented in Table J.13.1. Manual debris bed height measurements are reported in Table J.13.2. 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 between approximately 0.06 and 0.08 in below this datum. Therefore, 0.06 in has been added to the reported measurements. Test bed data are depicted in Figures J.13.1 through J.13.6.

Table J.13.1. Test Conditions

Quick-Look Report Date	11/29/05
Date of Test	11/28/05
Associated Test Case(s)	LANL: 6e2
Test Number and Data File Reference	051128_NC_2776_L2
Target Screen Debris Loading (g/m^2)	1522
Initial NUKON Mass Introduced (g)	18.51
NUKON R4 Target	10–12
Initial CalSil Mass Introduced (g)	9.25
CalSil R4 Target	1.5–1.9
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
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)	23.49

Table J.13.2. Preliminary Data

Test Phase	Velocity[a] (ft/sec)	Head Loss (in. H_2O)	Manual Debris Bed Height Measurement		Fluid Temperature (°C)
			Rim (in.)	Estimated Body[b] (in.)	
Rampup 1	0.09	73	0.67	-	21
	0.26(c)	273	-	-	21
	0.21(c)	283	-	-	22
	0.26(c)	385	0.61	0.20	22
	0.23(c)	390	-	-	22
	0.26(c)	492	0.61	0.20	22
	0.25(c)	515	-	-	22
	0.25(c)	560	0.61	0.22	24
	0.26	608	0.59	0.20	24
Ramp down 1	0.23	563	0.59	-	25
	0.2	436	0.57	-	25
	0.16	324	-	-	25
	0.1	164	0.57	-	25
Rampup 2	0.16	324	0.57	-	25
	0.21	478	0.57	-	25
	0.24	589	0.57	-	25
	0.26	686	0.55	-	25
Ramp down 2	0.23	612	0.55	-	26
	0.21	522	0.55	-	26
	0.16	360	0.55	-	26
	0.1	178	0.55	-	26
Rampup 3	0.16	361	0.55	-	26
	0.21	544	0.57	0.22	26
	0.23	663	0.53	-	27
	0.25	740	0.53	-	27
Ramp down 3	0.23	665	0.53	-	27
	0.21	592	0.53	-	27
	0.16	400	0.53	-	27
	0.1	203	0.57	-	27
Rampup 4	0.24	727	0.53	0.19	27
Ramp down 4	0.21	627	0.55	-	27
	0.16	409	0.55	-	27
	0.1	210	0.55	0.22	27
	0.05	78	0.57	0.24	27
	0.03	23	0.59	-	27
Rampup 5	0.1	204	0.57	-	27
	0.23	743	0.53	0.20	27
Ramp down 5	0.1	225	0.53	-	27

(a) All data taken with increased loop static pressure (~2.5 atm).

(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 distinct measurement was observed. Measurements taken upon bed retrieval are provided in Table J.13.4.

(c) Steady-state conditions were not achieved. Data included to illustrate the postulated effect of mobilization and addition to the debris bed of solids settled in test loop at the bed formation screen approach velocity of 0.1 ft/sec. "Jump" in screen approach velocity from 0.09 ft/sec to 0.26 ft/sec taken to replicate test condition LANL: 6e2 (Per personal communication from William Krotiuk to CW Enderlin, 11/28/05).

Table J.13.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in. H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.09	73	21	20
	0.26	273	21	20
	0.21	283	22	20
	0.26	385	22	20
	0.23	390	22	20
	0.26	492	22	20
	0.25	515	22	20
	0.25	560	24	20
	0.26	608	24	20
Ramp down 1	0.23	563	25	20
	0.2	436	25	20
	0.16	324	25	20
	0.1	164	25	20
Rampup 2	0.16	324	25	20
	0.21	478	25	20
	0.24	589	25	20
	0.26	686	25	20
Ramp down 2	0.23	612	26	20
	0.21	522	26	20
	0.16	360	26	20
	0.1	178	26	20
Rampup 3	0.16	361	26	20
	0.21	544	26	20
	0.23	662	27	20
	0.25	739	27	20
Ramp down 3	0.23	664	27	20
	0.21	591	27	20
	0.16	399	27	20
	0.1	202	27	20
Rampup 4	0.24	726	27	20
Ramp down 4	0.21	626	27	20
	0.16	408	27	20
	0.1	209	27	20
	0.05	78	27	20
	0.03	23	27	20
Rampup 5	0.1	203	27	20
	0.23	742	27	20
Ramp down 5	0.1	224	27	20

Table J.13.4. Post-Retrieval Debris Bed Measurements

Manual Debris Bed Measurements			
Rim Height (in.)	**Body Height (in.)**	**Total Bed Diameter (in.)**	**Body Diameter (in.)**
0.52	0.21	6.06	5.60

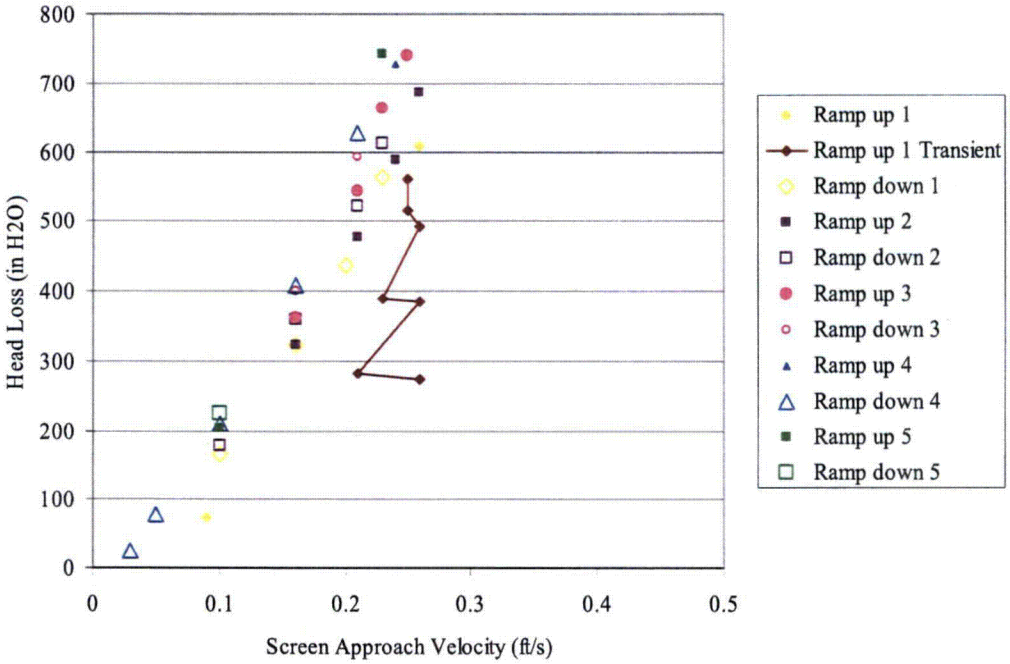


Figure J.13.1. Preliminary PNNL Data

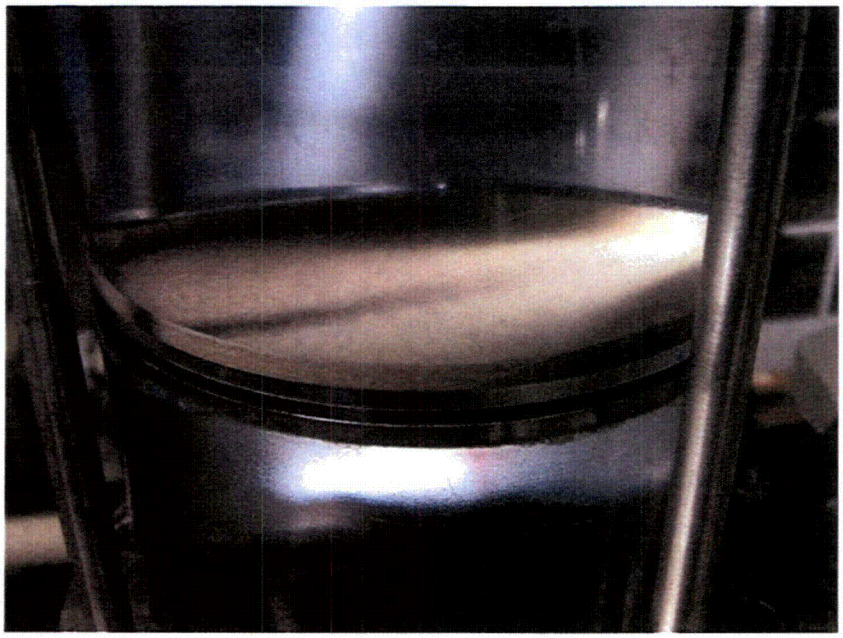


Figure J.13.2. Submerged 051128_NC_2776_L2 Debris Bed During Test

Figure J.13.3. 051128_NC_2776_L2 Debris Bed in Test Section After Retrieval, Top View.

Figure J.13.4. Close-Up of 051128_NC_2776_L2 Debris Bed in Test Section After Retrieval, Top View.

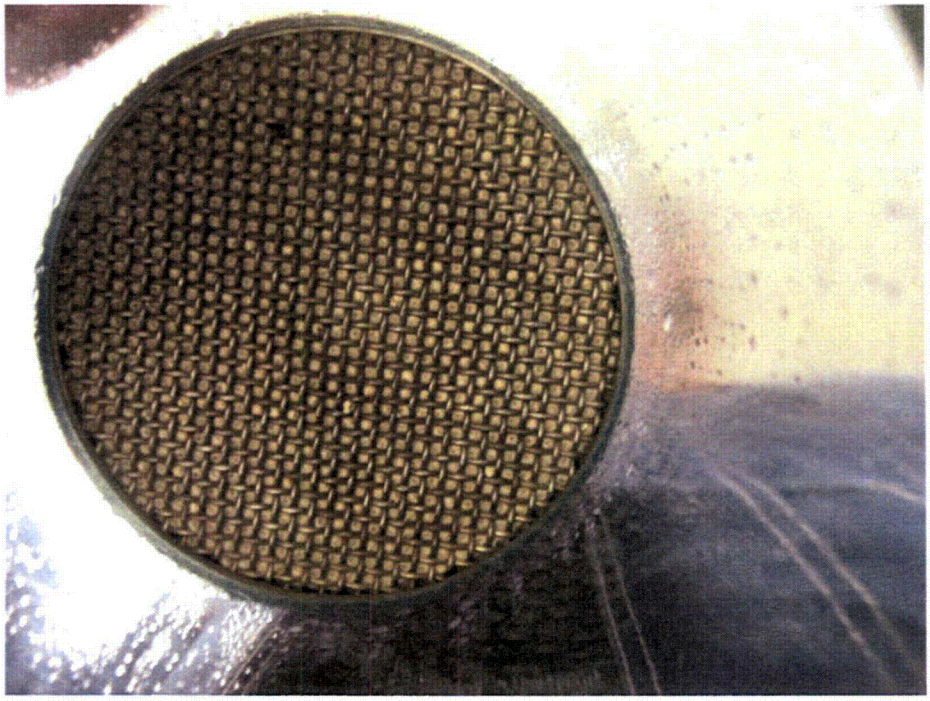


Figure J.13.5. 051128_NC_2776_L2 Debris Bed in Test Section After Retrieval, Bottom View

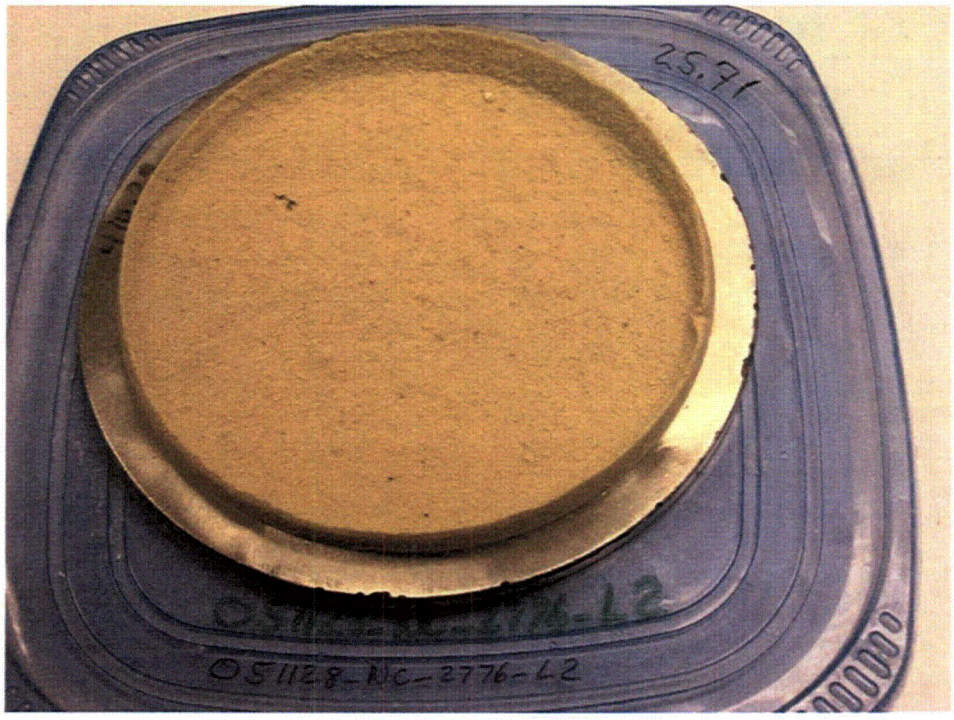


Figure J.13.6. 051128_NC_2776_L2 Debris Bed After Retrieval from Test Section. Indentation on Debris Bed Rim at 3:15 Orientation Due to Post-Retrieval Handling.

J.14 Quick-Look Report 6b – Preliminary PNNL Head Loss Test Data

All data contained herein is preliminary. The data was obtained from manual recordings taken from visual observation of the DAS screen readouts. In Table 2b, 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 bulk or "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 back-lighting, which shown through the rim, was observed.

Manual debris bed height measurements are reported in Table J.31. 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 between approximately 0.06 and 0.08 in below this datum. Therefore, 0.06 in has been added to the reported measurements.

Table J.14.1. Test Conditions

Quick-Look Report Date	11/21/05
Date of Test	11/15/05
Associated Test Case(s)	LANL: 6b
Test Number and Data File Reference	051115_NC_4098_L1
Target Screen Debris Loading (g/m^2)	2246.7
Initial NUKON Mass Introduced (g)	26.44
NUKON R4 Target	10 - 12
Initial CalSil Mass Introduced (g)	14.54
CalSil R4 Target	1.5 - 1.9
Initial Bed Formation Screen Approach Velocity (ft/sec)	0.20
Final Bed Formation Screen Approach Velocity (ft/sec)	0.09
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)	35.86

Table J.14.2. 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	0.09[b]	79	0.81	0.49	21
	0.1[b]	95	0.73	0.51	21
	0.1	95	0.73	0.51	21
	0.15	168	0.65	0.49	21
	0.19	244	0.65	0.49	21
	0.22	320	0.61	0.47	21
Ramp down 1	0.2	291	0.57	0.49	21
	0.15	208	0.57	< 0.45	21
	0.1	127	0.63	-	22
Rampup 2	0.15	208	0.61	-	22
	0.2	292	0.57	-	22
	0.23	375	0.61	-	22
Ramp down 2	0.2	316	0.57	-	22
	0.15	215	0.57	-	22
	0.1	131	0.57	-	22
Rampup 3	0.15	215	0.59	-	22
	0.2	318	0.57	-	22
	0.23	404	0.57	-	23
	0.25	461	0.57	-	23
Ramp down 3	0.23	424	0.57	-	23
	0.2	353	0.57	-	23
	0.15	243	0.57	-	23
	0.1	142	0.57	-	23
Rampup 4	0.15	244	0.57	-	23
	0.2	354	0.57	-	24
	0.25	505	0.57	-	24
Ramp down 4	0.2	373	0.57	-	24
	0.15	259	0.55	-	24
	0.1	142	0.57	-	24
Rampup 5	0.25	530	0.53	-	24
Ramp down 5	0.22	468	0.53	-	24
	0.2	411	0.53	-	24
	0.15	275	0.55	-	25
	0.1	155	0.55	-	25
	0.05	54	0.55	-	24
	0.02	10	0.57	-	24
Rampup 6	0.1	149	0.61	-	24
	0.2	425	0.55	-	24
	0.24	618	0.53	-	25
Ramp down 6	0.2	468	0.53	-	25
	0.1	189	0.55	-	25

(a) 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 distinct measurement was observed. Measurements taken upon bed retrieval are provided in Table J.32.

(b) Prior to increase of loop static pressure (~2.5 atm).

Table J.14.3. Corrected Data

Test Phase	Velocity (ft/sec)	Corrected Head Loss (in H_2O)	Average Loop Temperature (°C)	Pressure Manifold Temperature (°C)
Rampup 1	0.09	79	21	20
	0.1	95	21	20
	0.1	95	21	20
	0.15	168	21	20
	0.19	244	21	20
	0.22	320	21	20
Ramp down 1	0.2	291	21	20
	0.15	208	21	20
	0.1	127	22	20
Rampup 2	0.15	208	22	20
	0.2	292	22	20
	0.23	375	22	20
Ramp down 2	0.2	316	22	20
	0.15	215	22	20
	0.1	131	22	20
Rampup 3	0.15	215	22	20
	0.2	318	22	20
	0.23	404	23	20
	0.25	461	23	20
Ramp down 3	0.23	424	23	20
	0.2	353	23	20
	0.15	243	23	20
	0.1	142	23	20
Rampup 4	0.15	244	23	20
	0.2	354	24	20
	0.25	505	24	20
Ramp down 4	0.2	373	24	20
	0.15	259	24	20
	0.1	142	24	20
Rampup 5	0.25	530	24	20
Ramp down 5	0.22	468	24	20
	0.2	411	24	20
	0.15	275	25	20
	0.1	155	25	20
	0.05	54	24	20
	0.02	10	24	20
Rampup 6	0.1	149	24	20
	0.2	425	24	20
	0.24	618	25	20
Ramp down 6	0.2	468	25	20
	0.1	189	25	20

Table J.14.4. Post Retrieval Debris Bed Measurements

Manual Debris Bed Measurements			
Rim Height (in.)	**Body Height (in.)**	**Total Bed Diameter (in.)**	**Body Diameter (in.)**
0.71	0.37	6.06	5.51

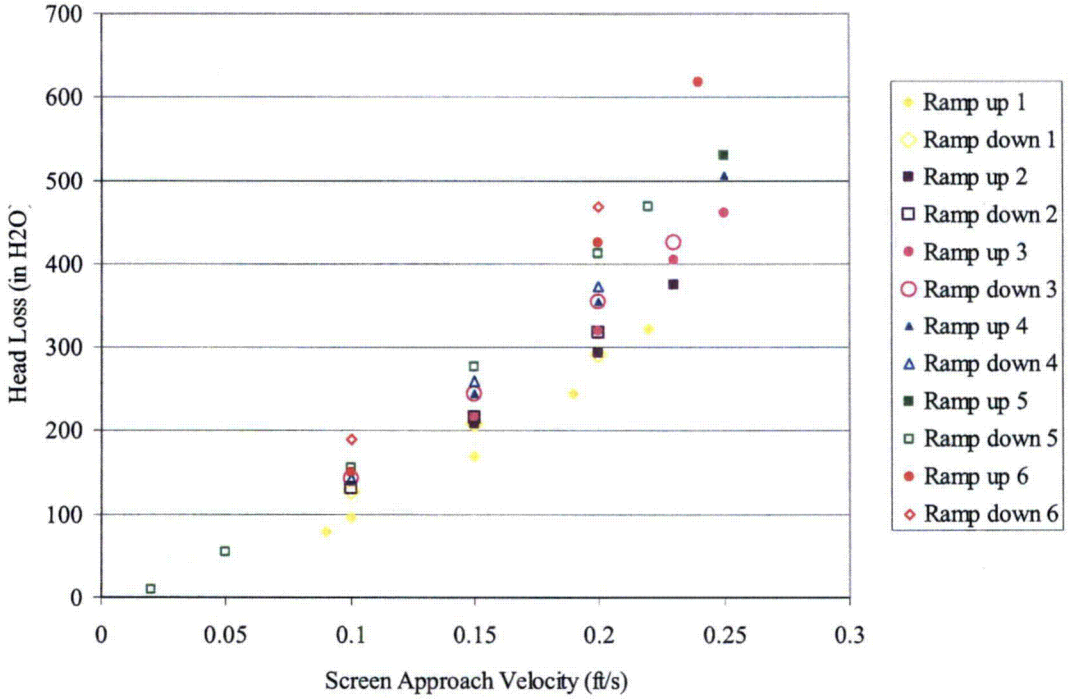


Figure J.14.1. Preliminary PNNL Data

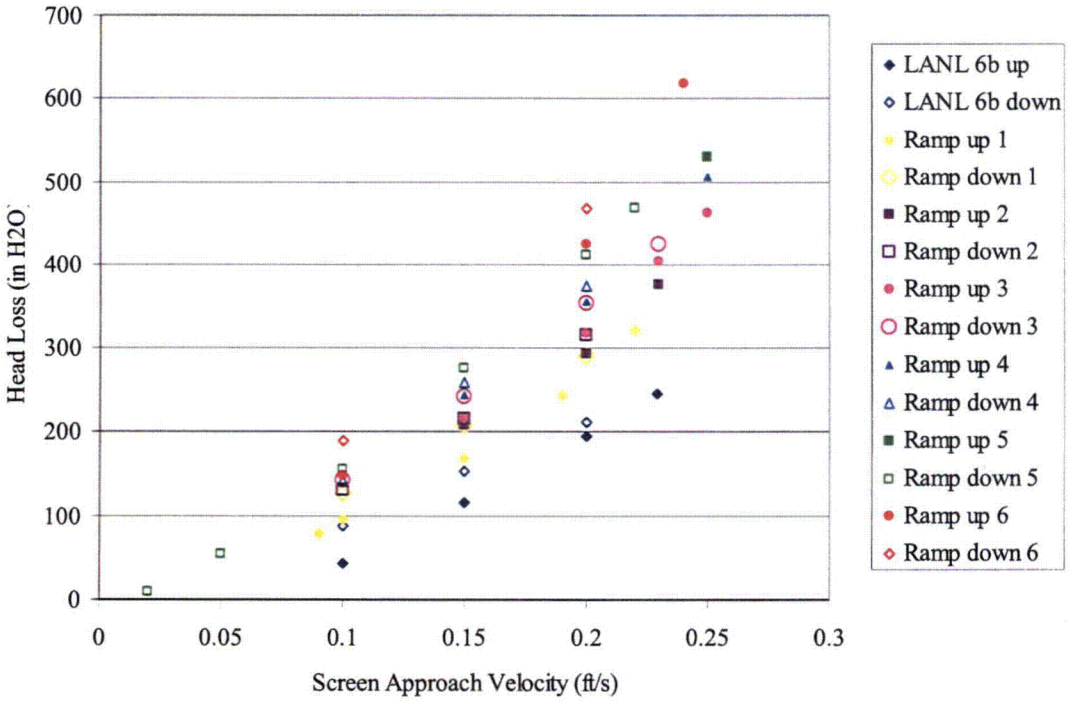


Figure J.14.2. Comparison of Preliminary PNNL Data to Previous Results. BT Denotes PNNL Benchtop.

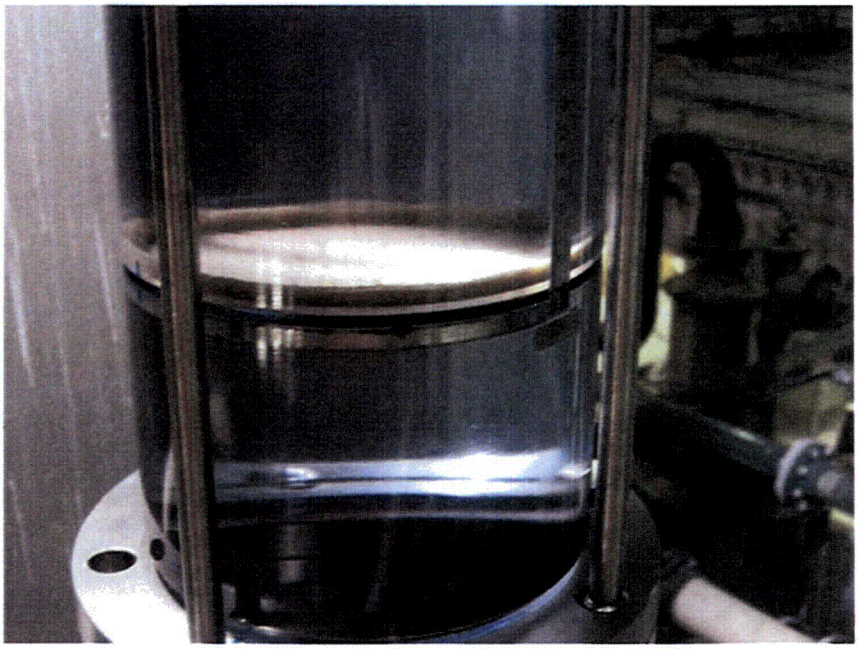


Figure J.14.3. Submerged 051115_NC_4098_L1 Debris Bed During Test.

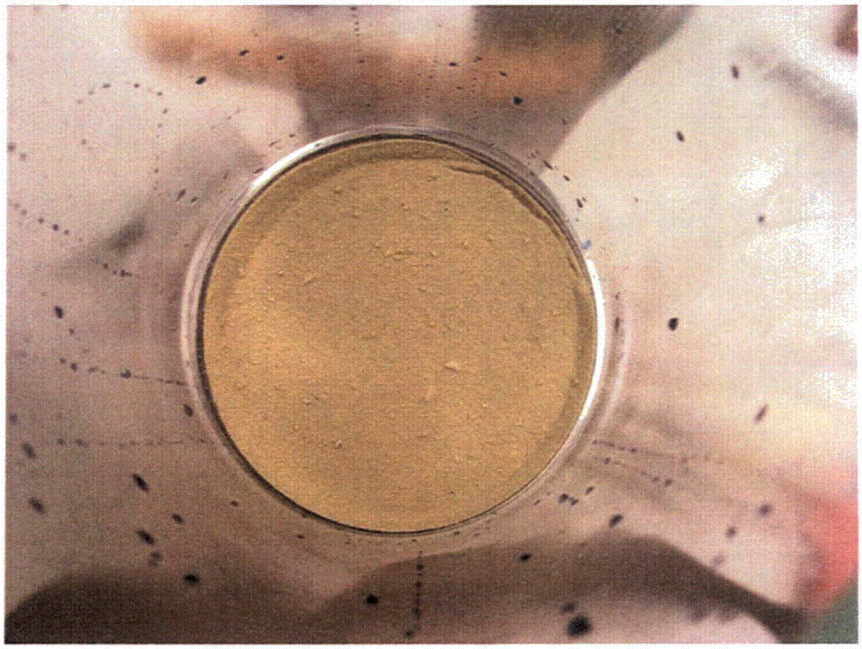


Figure J.14.4. 051115_NC_4098_L1 Debris Bed in Test Section After Retrieval, Top View. Apparent gap from debris bed to test-section wall and collapsed rim at the 2:00 position were caused after test section retrieval from test loop and prior to measurements being taken.

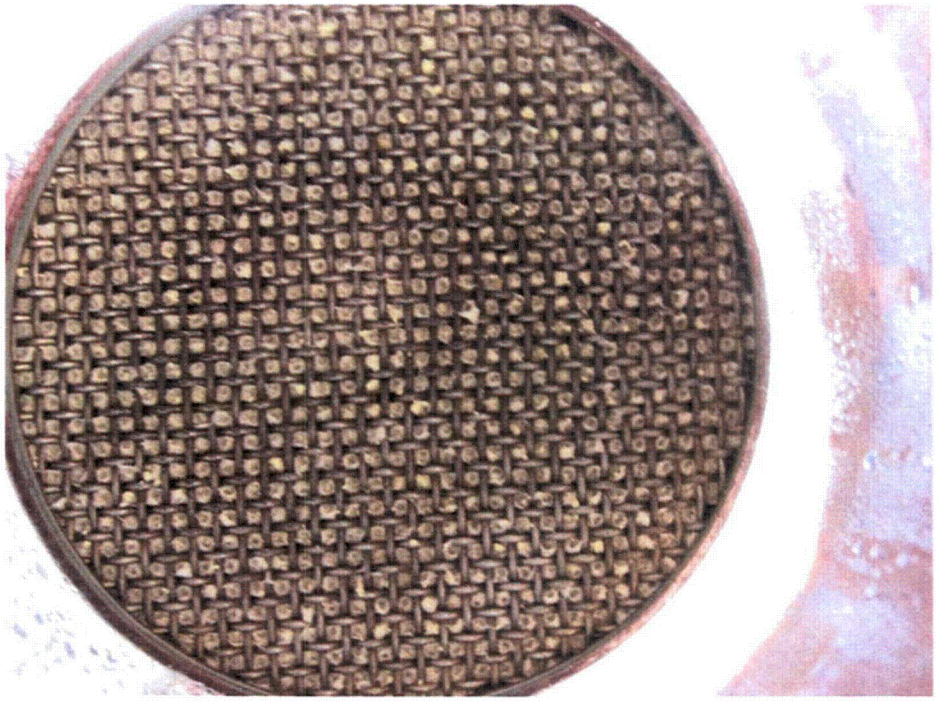


Figure J.14.5. 051115_NC_4098_L1 Debris Bed in Test Section After Retrieval, Bottom View.

Figure J.14.6. 051115_NC_4098_L1 Debris Bed After Retrieval from Test Section. Collapsed rim was caused following test section retrieval from test loop.

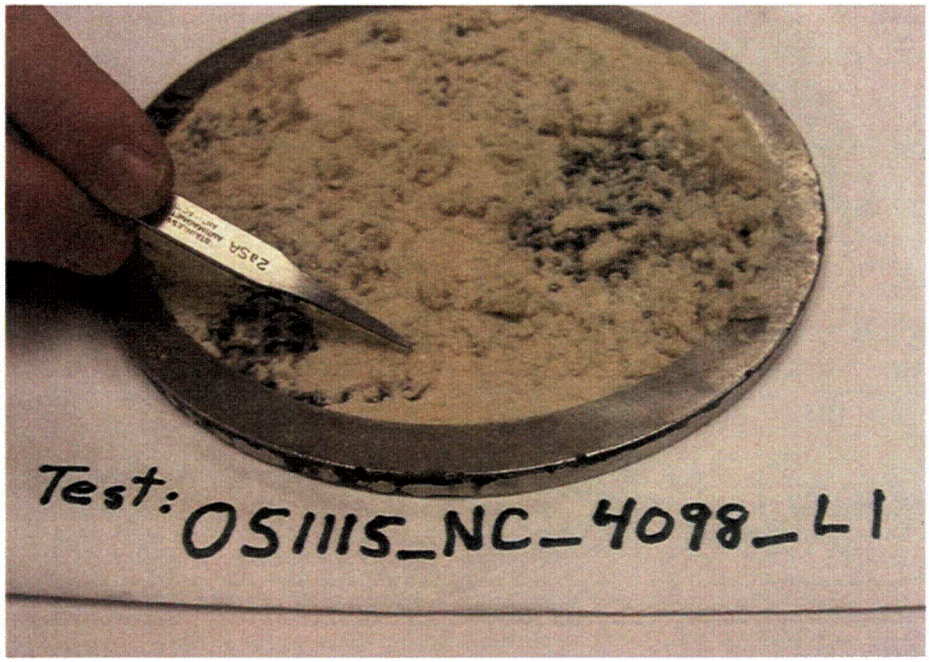


Figure J.14.7. 051115_NC_4098_L1 Debris Bed After Retrieval from Test Section and During Removal From Screen. CalSil particulate is visible throughout debris bed (white particles). Large particle is pointed out.

J.15 Quick-Look Report for PNNL Tests 060807_NC_0708_LP1 and 060807_NC_0708_LP2, Test Condition Series at Priority 6, 54°C Preliminary PNNL Head Loss Test Data

All data contained herein is preliminary. Test conditions are reported in Table 1, and preliminary test data is reported in Tables 2a - 2b. The data was 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 readouts. The value reported is from the differential pressure (DP) meter with the most appropriate span for the given range of head loss readings. In Table 2c-2d, 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 provided test plan and communication with the client.[a] 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 back-lighting, which shown through the rim, was observed. These manual measurements of the debris-bed body are not

[a] 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.

always obtainable because a difference in back lightning 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 2a - 2b. 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 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. 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 4. 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 J.15.1. Test Conditions

Quick-Look Report Date	9/5/06
Date of Test	8/7/06
Associated Test Case(s)	Series 2 Priority 6
Test Number(s) and Data File Reference(s)	060807_NC_0708_LP1 060807_NC_0708_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)	380
Initial NUKON Mass Introduced (g)	4.04
NUKON R4 Target	10 - 12
Initial CalSil Mass Introduced (g)	3.04
CalSil R4 Target	< 1.55, no chunks
Debris Loading Sequence	Debris constituents premixed prior to introduction into the test loop.
Initial Bed Formation Screen Approach Velocity (ft/sec)	0.10
Final Bed Formation Screen Approach Velocity (ft/sec)	0.10
Bed Formation Time (min)	67
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)	4.86

Table J.15.2. Preliminary Data, LP1

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement[c]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Bed Formation	0.10	10[b]	-	-	55
Rampup 1	0.10	11	-	-	55
Rampup 1 (prefiltering)	0.20	30	-	-	55
Rampup 1 (post-filtering)	0.20	32	-	-	54
Ramp down 1	0.10	13	-	-	54
Ramp down 1	0.05	6	-	-	55
Ramp down 1	0.02	2	-	-	54
Rampup 2	0.10	13	-	-	55
Rampup 2	0.20	35	-	-	55
Ramp down 2	0.10	14	-	-	55
Ramp down 2	0.02	3	-	-	55
Rampup 3	0.10	15	-	-	55
Rampup 3	0.20	39	-	-	55
Ramp down 3	0.10	16	-	-	55
Ramp down 3	0.02	2	-	-	55
Rampup 4	0.10	16	-	-	56

(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) Pressure measurement taken prior to 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 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 J.15.3. Preliminary Data, LP2

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement[c]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Rampup 1	0.10	31	-	-	37
Rampup 1	0.20	64	-	-	37
Ramp down 1	0.10	27	-	-	37
Ramp down 1	0.02	3	-	-	37
Rampup 2	0.10	28	-	-	37

(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) Pressure measurement taken prior to 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 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 J.15.4. 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	9	55	23
Rampup 1	0.10	10	55	23
Rampup 1 (prefiltering)	0.20	29	55	25
Rampup 1 (post-filtering)	0.20	31	54	26
Ramp down 1	0.10	12	54	26
Ramp down 1	0.05	5	55	26
Ramp down 1	0.02	1	54	27
Rampup 2	0.10	12	55	27
Rampup 2	0.20	34	55	28
Ramp down 2	0.10	13	55	28
Ramp down 2	0.02	2	55	28
Rampup 3	0.10	14	55	29
Rampup 3	0.20	38	55	29
Ramp down 3	0.10	15	55	29
Ramp down 3	0.02	2	25	29
Rampup 4	0.10	15	55	30

Table J.15.5. 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	31	37	33
Rampup 1	0.20	64	37	33
Ramp down 1	0.10	27	37	33
Ramp down 1	0.02	3	37	33
Rampup 2	0.10	28	36	33

Table J.15.6. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.15	0.05	6.065	N/A

Table J.15.7. 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
060807_LP1_0.1_80_RU1	0.20	0.09	0.07	5.23	1.50	2.50
060807_LP1_0.2_81_RU1	0.21	0.08	0.06	5.27	1.31	2.26
060807_LP1_0.02_89_RD2	0.20	0.08	0.06	5.25	1.30	2.24
060807_LP1_0.1_90_RU3	0.20	0.07	0.05	5.37	1.13	1.92
060807_LP2_0.2_98_RU1	0.17	0.04	0.02	5.42	0.46	1.01
060807_LP2_0.1_01_RU2	0.17	0.05	0.03	5.59	0.74	1.17

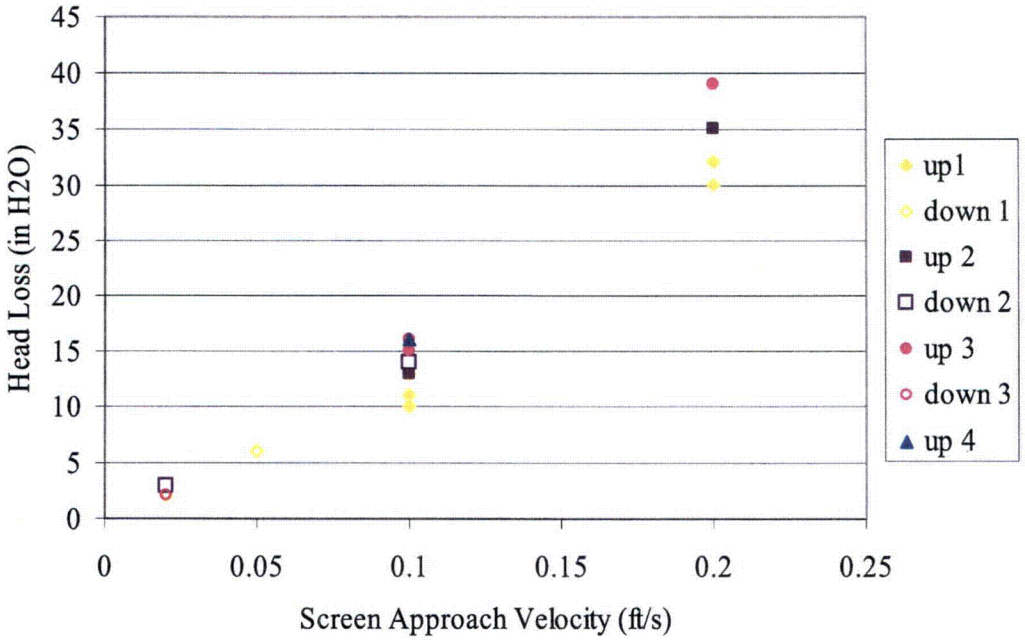


Figure J.15.1. Preliminary PNNL Data, LP1.

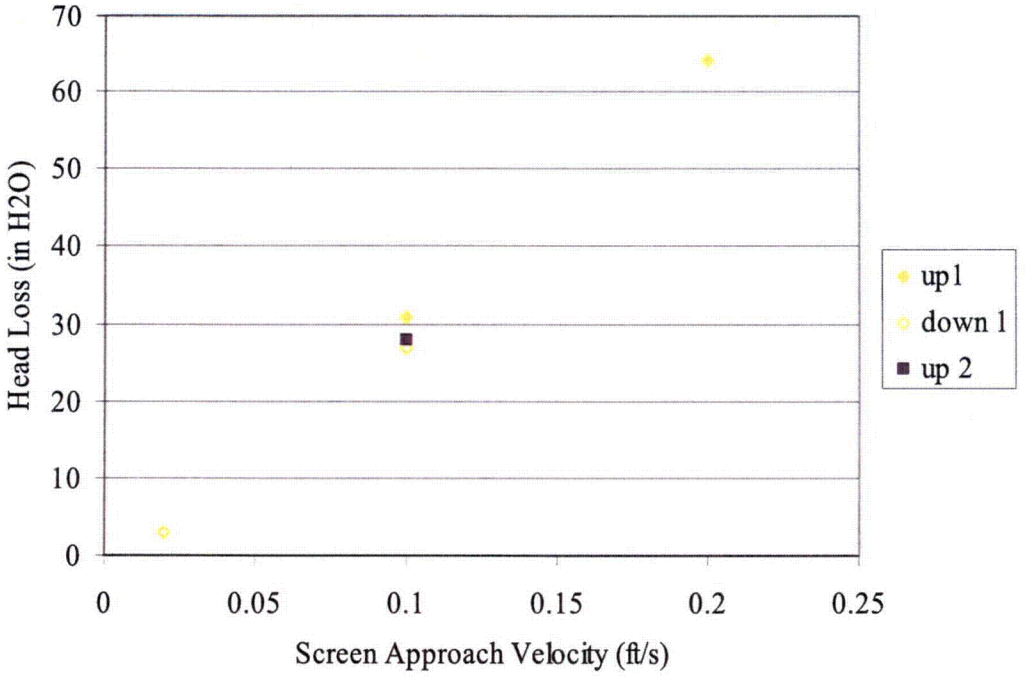


Figure J.15.2. Preliminary PNNL Data, LP2.

Figure J.15.3. Debris Bed in Test Section After Retrieval, Top View. Disturbed post-test.

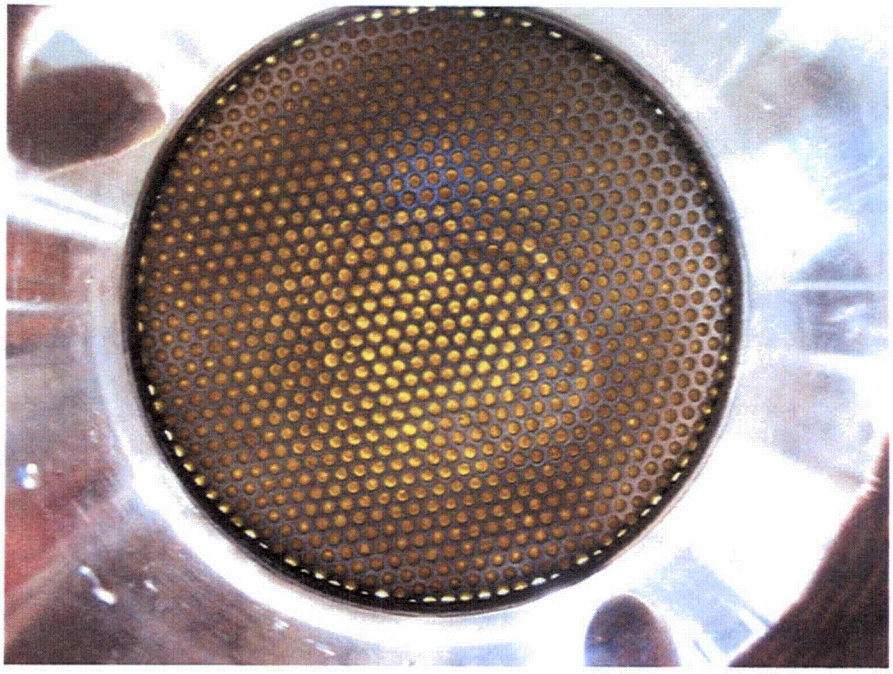


Figure J.15.4. Debris Bed in Test Section After Retrieval, Bottom View.

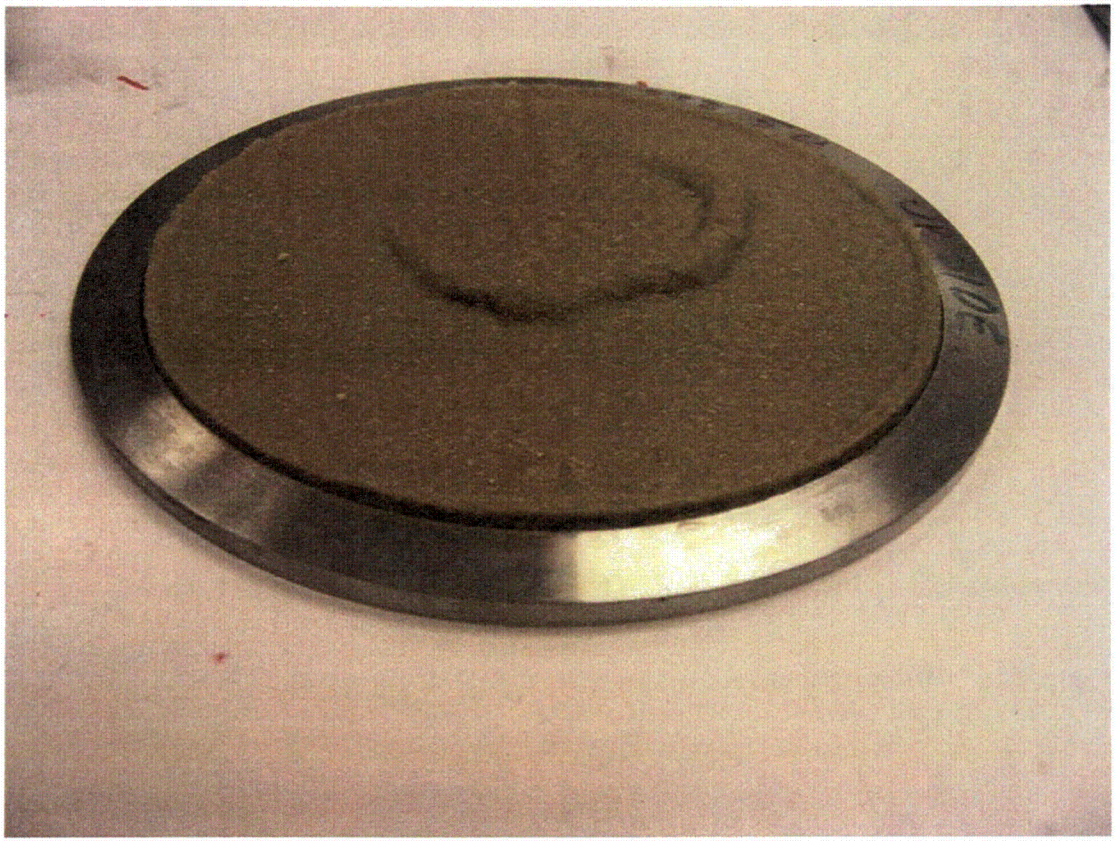


Figure J.15.5. Debris Bed After Retrieval from Test Section. Disturbed post-test.

J.16 Quick-Look Report for PNNL Tests 060809_NC_0708_LP1 and 060809_NC_0708_LP2, Test Condition Series at Priority 6, 82°C

All data contained herein is preliminary. Test conditions are reported in Table 1, and preliminary test data is reported in Tables 2a - 2b. The data was 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 readouts. The value reported is from the differential pressure (DP) meter with the most appropriate span for the given range of head loss readings. In Table 2c-2d, 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 provided test plan and communication with the client.[a] 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 bulk or "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

[a] 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.

difference in the back-lighting, which shown through the rim, was observed. These measurements are referred to as "manual". Manual measurements of the debris-bed body are not always obtainable because a difference in back lightning 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 2a - 2b. 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 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. 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 4. 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 J.16.1. Test Conditions

Quick-Look Report Date	9/5/06
Date of test	8/9/06
Associated test case(s)	Series 2 Priority 6
Test number(s) and data file reference(s)	060809_NC_0708_LP1 060809_NC_0708_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)	380
Initial NUKON mass introduced (g)	4.04
NUKON R4 target	10 - 12
Initial CalSil mass introduced (g)	3.04
CalSil R4 target	< 1.55, no chunks
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop.
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	82
Calculated number of representative circulations during debris bed formation (from estimated 9-minute circulation time)	9
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)	2.98

Table J.16.2. Preliminary Data, LP1

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement[c]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Bed Formation	0.10	8[b]	-	-	83
Rampup 1	0.10	8	-	-	82
Rampup 1 (prefiltering)	0.20	16	-	-	82
Rampup 1 (post-filtering)	0.20	13	-	-	82
Ramp down 1	0.10	7	-	-	82
Ramp down 1	0.05	4	-	-	82
Ramp down 1	0.02	3	-	-	79
Rampup 2	0.10	6	-	-	82
Rampup 2	0.20	13	-	-	82
Ramp down 2	0.10	7	-	-	82
Ramp down 2	0.02	3	-	-	80
Rampup 3	0.10	7	-	-	83
Rampup 3	0.20	13	-	-	82
Ramp down 3	0.10	7	-	-	82
Ramp down 3	0.02	3	-	-	80
Rampup 4	0.10	6	-	-	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) Pressure measurement taken prior to 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 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 J.16.3. Preliminary Data, LP2

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement[c]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Rampup 1	0.10	7	-	-	54
Rampup 1	0.20	17	-	-	54
Ramp down 1	0.10	8	-	-	54
Ramp down 1	0.02	2	-	-	53
Rampup 2	0.10	7	-	-	54

(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) Pressure measurement taken prior to 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 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 J.16.4. 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	5	83	24
Rampup 1	0.10	5	82	24
Rampup 1 (prefiltering)	0.20	13	82	24
Rampup 1 (post-filtering)	0.20	10	82	24
Ramp down 1	0.10	4	82	25
Ramp down 1	0.05	1	82	25
Ramp down 1	0.02	0	79	25
Rampup 2	0.10	3	82	25
Rampup 2	0.20	10	82	25
Ramp down 2	0.10	4	82	25
Ramp down 2	0.02	0	80	25
Rampup 3	0.10	4	83	25
Rampup 3	0.20	10	82	25
Ramp down 3	0.10	4	82	25
Ramp down 3	0.02	0	80	25
Rampup 4	0.10	3	83	25

Table J.16.5. 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	6	54	26
Rampup 1	0.20	16	54	26
Ramp down 1	0.10	7	54	26
Ramp down 1	0.02	1	55	26
Rampup 2	0.10	7	54	26

Table J.16.6. Post-Retrieval Debris Bed Measurements

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

Table J.16.7. 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
060809_LP1_0.1_16_RU1	0.10	0.08	0.06	5.81	1.59	1.78
060809_LP1_0.2_18_RU1	0.09	0.06	0.04	5.78	1.05	1.22
060809_LP1_0.2_27_RU3	0.09	0.06	0.04	5.77	1.05	1.22
060809_LP1_0.02_29_RD3	0.10	0.08	0.06	5.67	1.52	1.81
060809_LP1_0.1_30_RU4	0.09	0.06	0.04	5.85	1.08	1.21
060809_LP2_0.2_32_RU1	0.07	0.05	0.03	5.86	0.81	0.90
060809_LP2_0.1_35_RU2	0.07	0.05	0.03	5.88	0.81	0.90

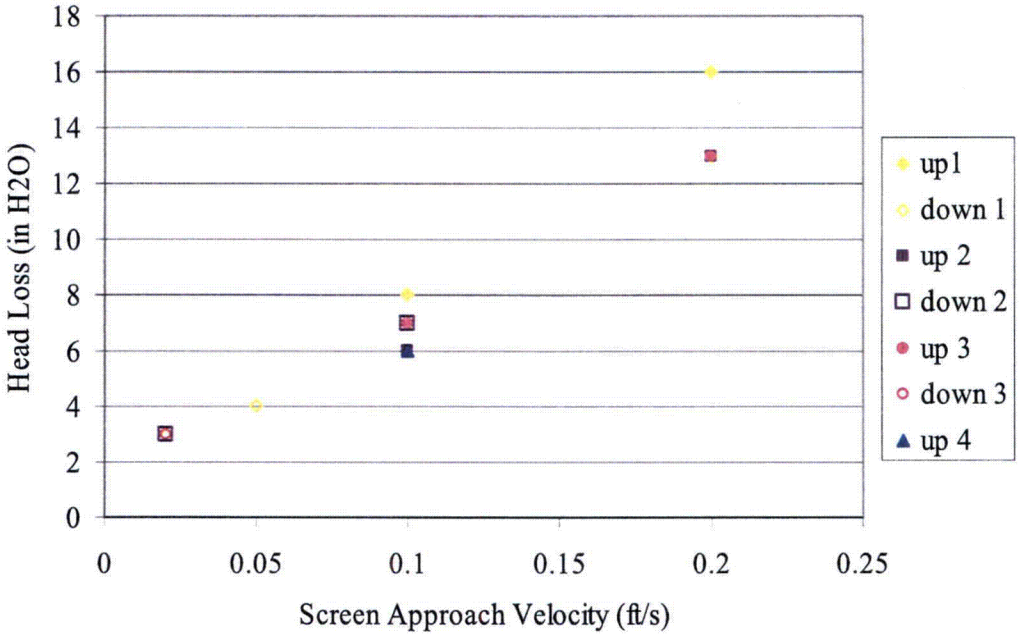


Figure J.16.1. Preliminary PNNL Data, LP1.

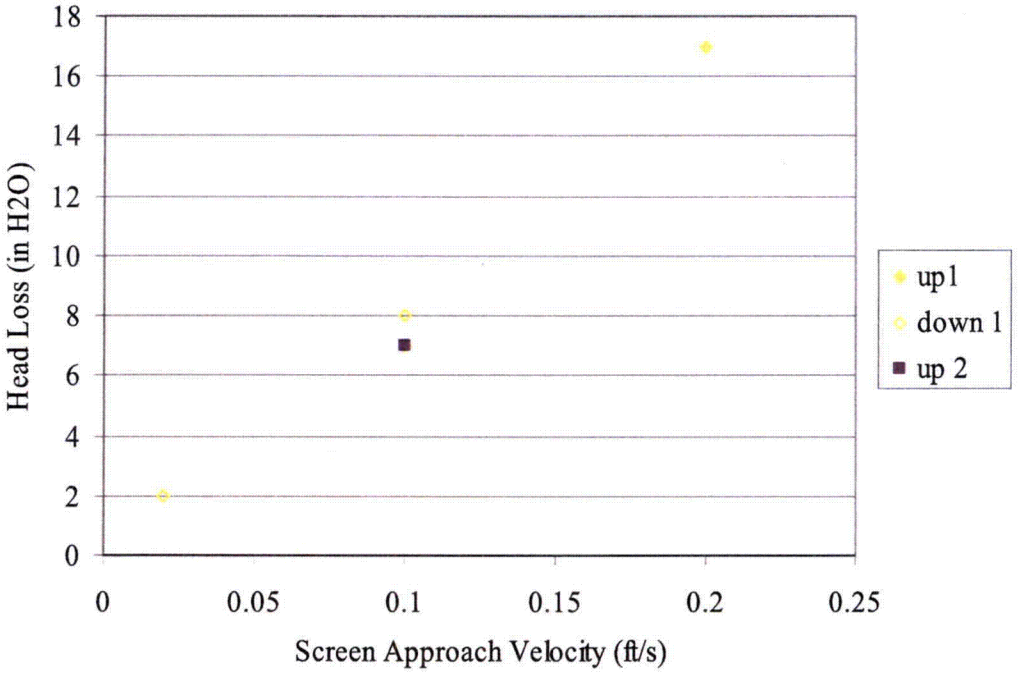


Figure J.16.2. Preliminary PNNL Data, LP2

Figure J.16.3. Debris Bed in Test Section After Retrieval, Top View. Disturbed post-test.

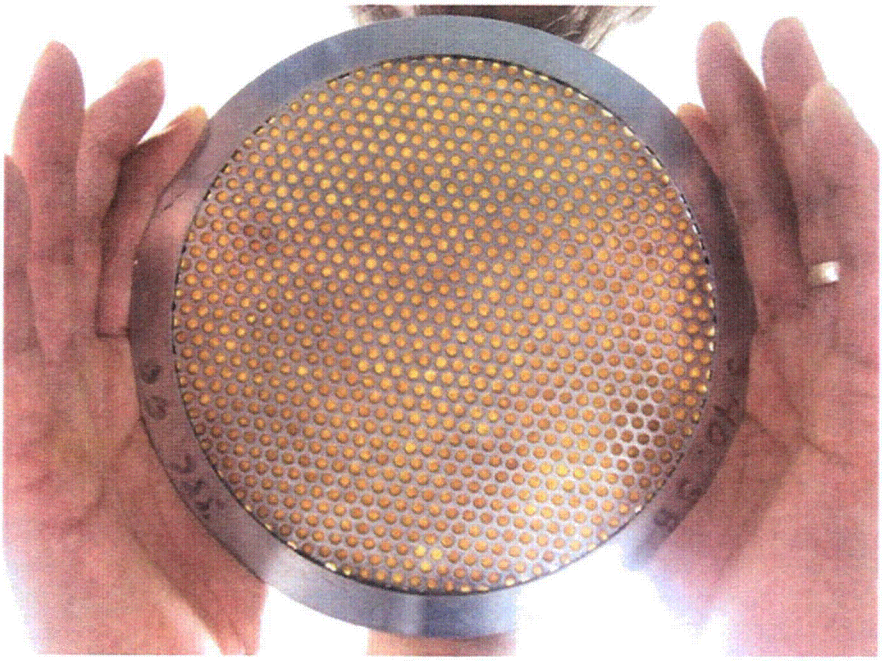


Figure J.16.4. Debris Bed in Test Section After Retrieval, Bottom View.

J.17 Quick-Look Report for PNNL Tests 060817_NC_2024_LP1 and 060817_NC_2024_LP2, Test Condition Series at Priority 4, 54°C

All data herein are preliminary. Test conditions are reported in Table J.17.1, and preliminary test data are reported in Tables J.17.2 and J.17.3. The data was 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. In Tables J.17.4 through J.17.5, 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 provided test plan and communication with the client.[a] 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 J.17.2 and J.17.3. 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 J.17.6. 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 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 J.17.7. 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.

[a] 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 J.17.1. Test Conditions

Quick-Look Report Date	9/5/06
Date of test	8/17/06
Associated test case(s)	Series 2 Priority 4
Test number(s) and data file reference(s)	060817_NC_2024_LP1 060817_NC_2024_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)	1,086
Initial NUKON mass introduced (g)	13.49
NUKON R4 target	10 - 12
Initial CalSil mass introduced (g)	6.75
CalSil R4 target	< 1.55, no chunks
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop.
Initial bed formation screen approach velocity (ft/sec)	0.10
Final bed formation screen approach velocity (ft/sec)	0.10
Bed formation time (min)	72
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)	15.11

Table J.17.2. Preliminary Data, LP1

Test Phase	Velocity (ft/sec)	Head Loss[(a)] (in. H_2O)	Manual Debris Bed Height Measurement[(c)]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Bed Formation	0.10	17[(b)]	0.38	0.18	55
Rampup 1	0.10	19	0.38	0.18	56
Rampup 1 (prefiltering)	0.20	89	0.34	0.18	54
Rampup 1 (post-filtering)	0.20	106	0.38	0.18	53
Ramp down 1	0.10	40	0.38	0.18	54
Ramp down 1	0.05	15	0.38	0.18	54
Ramp down 1	0.02	5	0.38	0.18	54
Rampup 2	0.10	40	0.38	0.18	54
Rampup 2	0.20	170	0.38	0.12	55
Ramp down 2	0.10	64	0.38	0.12	55
Ramp down 2	0.02	7	0.38	0.14	55
Rampup 3	0.10	64	0.38	0.14	55
Rampup 3	0.20	216	0.38	-	55
Ramp down 3	0.10	75	0.38	-	55
Ramp down 3	0.02	7	0.38	0.12	54
Rampup 4	0.10	79	0.38	-	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) Pressure measurement taken prior to 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 off the screen at which there was a difference in the amount of backlighting showing through the rim. Blank (-) entries indicate that no measurement was taken because no difference in backlighting was observed.

Table J.17.3. Preliminary Data, LP2

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement[c]		Fluid Temperature (°C)
			Rim (in.)	Estimated Body (in.)	
Rampup 1	0.10	128	0.38	-	30
Rampup 1	0.20	298	0.38	-	30
Ramp down 1	0.10	118	0.38	0.12	29
Ramp down 1	0.02	11	0.38	0.12	29
Rampup 2	0.10	126	0.38	0.12	29

(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) Pressure measurement taken prior to 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 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 J.17.4. 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	15	55	22
Rampup 1	0.10	17	56	22
Rampup 1 (prefiltering)	0.20	88	54	22
Rampup 1 (post-filtering)	0.20	105	53	22
Ramp down 1	0.10	39	54	22
Ramp down 1	0.05	14	54	22
Ramp down 1	0.02	4	54	23
Rampup 2	0.10	39	54	23
Rampup 2	0.20	169	55	22
Ramp down 2	0.10	63	55	24
Ramp down 2	0.02	6	55	24
Rampup 3	0.10	63	55	24
Rampup 3	0.20	215	55	24
Ramp down 3	0.10	74	55	25
Ramp down 3	0.02	7	25	23
Rampup 4	0.10	78	55	25

Table J.17.5. 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	128	30	22
Rampup 1	0.20	298	30	22
Ramp down 1	0.10	118	29	22
Ramp down 1	0.02	11	29	22
Rampup 2	0.10	126	29	21

Table J.17.6. Post-Retrieval Debris Bed Measurements

Post-Retrieval Manual Debris Bed Measurements			
Rim Height (in.)	Body Height (in.)	Total Bed Diameter (in.)	Body Diameter (in.)
0.29	0.23	6.065	N/A

Table J.17.7. 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
060817_LP1_0.1_49_RU1	0.40	0.34	0.32	5.48	7.56	9.46
060817_LP1_0.2_51_RU1	0.34	0.28	0.26	5.25	5.62	7.80
060817_LP1_0.2_60_RU3	0.25	0.19	0.17	5.43	3.94	5.14
060817_LP1_0.02_62_RD3	0.28	0.25	0.23	5.47	5.41	6.78
060817_LP1_0.1_63_RU4	0.26	0.20	0.18	5.49	4.26	5.41
060817_LP2_0.2_65_RU1	0.22	0.16	0.14	5.44	3.26	4.27
060817_LP2_0.1_68_RU2	0.23	0.17	0.15	5.56	3.64	4.52

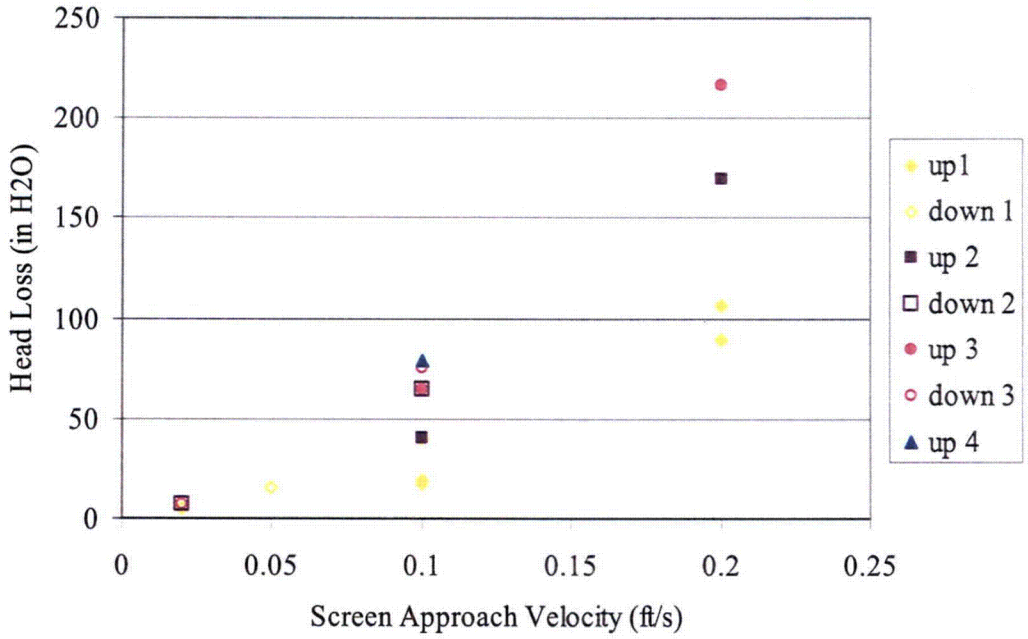


Figure J.17.1. Preliminary PNNL Data, LP1.

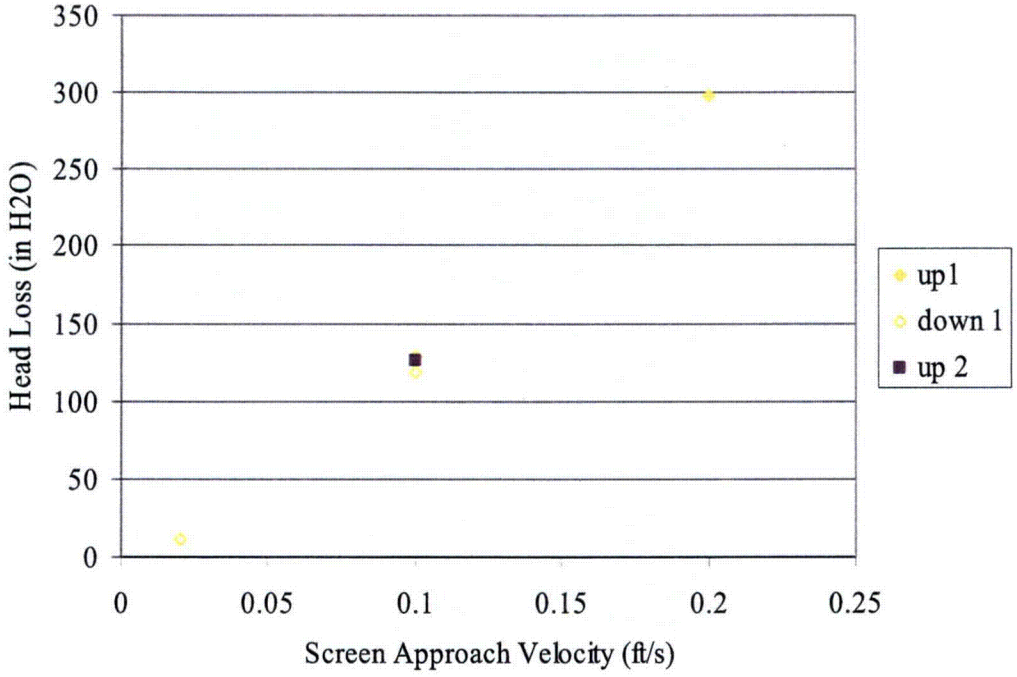


Figure J.17.2. Preliminary PNNL Data, LP2

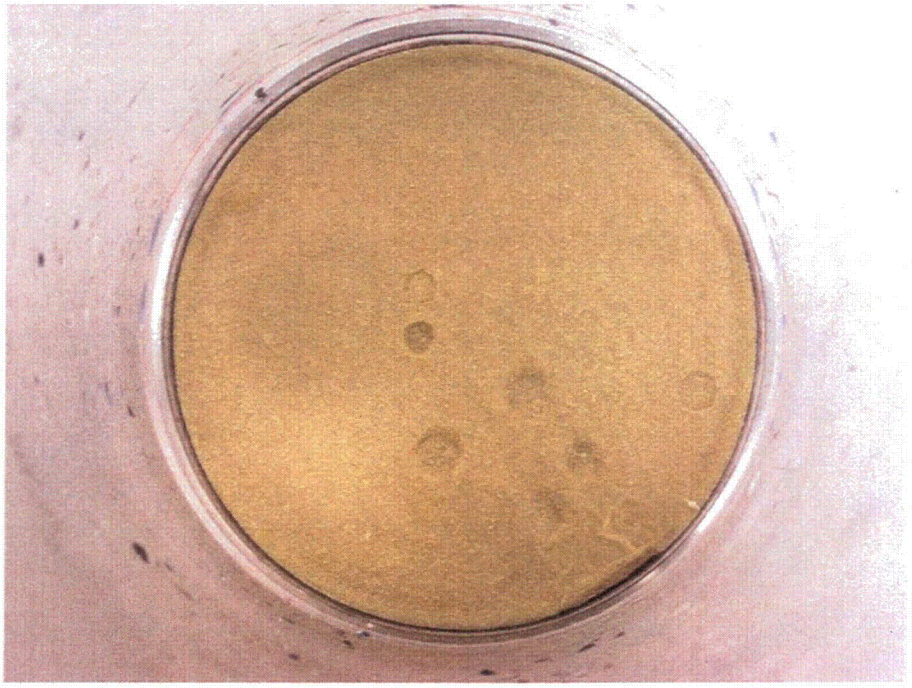


Figure J.17.3. Debris Bed in Test Section After Retrieval, Top View. Disturbed post-test.

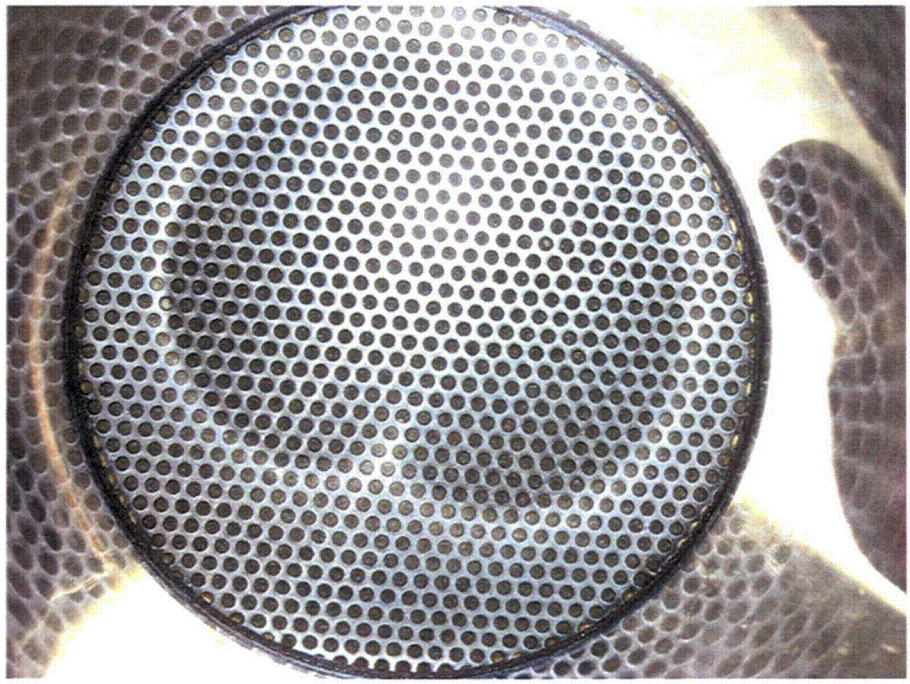


Figure J.17.4. Debris Bed in Test Section After Retrieval, Bottom View.

Figure J.17.5. Debris Bed After Retrieval from Test Section. Disturbed post-test.

Appendix K – Quick-Look Report for PNNL Series II Coating Priority 5 and Associated Benchtop Tests

Appendix K – Quick-Look Report for PNNL TESTS 060501_PQC_2609_LP1 and 060501_PQC_2609_LP2, and 060504_PQZ_2609_LP1, Test Condition Series II Coating Priority 5 and Associated Benchtop Tests

All data contained herein are preliminary. Test conditions are reported in Tables K.1 and K.2, and preliminary test data are reported in Tables K.3–K.5. The data were obtained from manual recordings of visual observations of the data acquisition system (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 in a memo from CW Enderlin 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.).

Table K.1.1. Test Conditions, ALK Coating

Quick-Look Report date	6/30/06
Date of test	5/1/06
Associated test case(s)	Series II Coating Priority 5
test number(s) and data file reference(s)	060501_PQC_2609_LP1 060501_PQC_2609_LP 2
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
Screen area (m^2)	0.0185
Target screen debris loading (g/m^2)	1400
Initial processed coating mass introduced (g)	13.05
Processed coating R4 target	1.4
Initial CalSil mass introduced (g)	13.05
1/4 in. coating R4 target	N/A
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop
Initial bed formation screen approach velocity (ft/sec)	0.20[a,b]
Final bed formation screen approach velocity (ft/sec)	0.20
Bed formation time (min)	60
Calculated number of representative circulations during debris bed formation (from estimated 5 minute circulation time)	12
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)	15.04

(a) The screen approach velocity for bed formation for this ALK coating test was increased to the maximum velocity of the test plan, 0.20 ft/sec, based on the ALK Priority 5 test in the benchtop loop (see *060428_PQC_1136_BP_Prel Rslts.doc*).

(b) The mobilized debris for flow circulation immediately after introducing debris into the loop was judged by visual observation to be reduced by settling rather than collecting on the plate. Settled material was mobilized into the flow by tapping the horizontal flow region of the test loop at the debris injection level with a rubber hammer until limited additional debris was seen to be mobilized. This hammer technique was conducted intermittently for approximately 20 min after debris injection.

Table K.1.2. Test Conditions, ZE Coating

Quick-Look Report date	6/30/06
Date of test	5/4/06
Associated test case(s)	Series II Coating Priority 5
Test number(s) and data file reference(s)	060504_PQZ_2609_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
Screen area (m^2)	0.0185
Target screen debris loading (g/m^2)	1400
Initial processed coating mass introduced (g)	13.05
Processed coating R4 target	1.4
Initial CalSil mass introduced (g)	13.05
1/4 in. coating R4 target	N/A
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop
Initial bed formation screen approach velocity (ft/sec)	0.30[(a)]
Final bed formation screen approach velocity (ft/sec)	0.70[(a)]
Initial (0.30 ft/sec) bed formation time (min)	60
Calculated number of representative circulations during debris bed formation (from estimated 3-minute circulation time)	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)	15.85

(a) The screen approach velocity for bed formation for this ZE coating test was increased above the maximum velocity of the test plan, 0.20 ft/sec, based on the ALK Priority 1 and 5 tests conducted by PNNL. The mobilized debris for flow circulations immediately after debris introduction into the loop was judged, by visual observation, to be reduced by settling rather than collecting on the plate. Thus settled material was mobilized into the flow by tapping the horizontal flow region of the test loop at the debris injection level with a rubber hammer. Eight tapping periods were conducted within 5 minutes of introducing the debris. By the 8th tapping period, approximately 10 minutes after debris injection, material mobilization to the test section/plate was minimal, as judged by visual observation. The debris bed was incomplete with ~20% of the plate area exposed. The 1/4-in.-square ZE debris on the perforated plate was visually observed to approximate the loaded amount. The processed debris was visually observed to be passing through the plate (and 1/4-in. debris retained thereon) during the early portion of the bed formation test phase. This processed debris concentration in the flow was visually observed to decrease with time without readily apparent buildup on the debris bed. Thus it was judged to have settled in the loop. The screen approach velocity was increased to 0.7 ft/sec (see 060502_POC_2609_LP1 preliminary data report). The processed particulate concentration in the flow was visually observed to increase, minimal 1/4-in. debris was added, and the processed particulate collected on the plate over the 45-minute hold period. The measured debris bed head loss increased by 60% (10 to 16 in. H_2O) over this period. The incomplete debris bed velocity matrix was subsequently used due to incomplete bed formation.

During the PNNL insulation debris testing (i.e., 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 debris beds formed with Ameron's Amercoat 5450 alkyd topcoat (ALK) and Ameron's Dimetcote 6 inorganic Zn primer with Amercoat 90 epoxy topcoat (ZE) coating were not obtainable given (depending on the test) the incomplete and varied nature of the debris bed. Photographs for in situ debris bed height measurements using optical triangulation were also taken (Figures K.5–K.13). No analysis of these pictures has been conducted due to the incompleteness of the debris beds.

Post-retrieval debris bed height measurements taken upon bed retrieval are provided in Tables K.6 and K.7. Results from the associated benchtop test cases conducted to determine the target debris loading for the large-scale loop are presented below.

Table K.1.3. Preliminary Data for Test 060501_PQC_2609_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	0.2	66[c]	N/A	N/A	18
Rampup 1 (prefiltering)	0.2	66	N/A	N/A	18
Rampup 1 (post-filtering)	0.2	66	N/A	N/A	18
Ramp down 1	0.1	22	N/A	N/A	18
Ramp down 1	0.05	7	N/A	N/A	18
Ramp down 1	0.02	4	N/A	N/A	18
Rampup 2	0.1	23	N/A	N/A	18
Rampup 2	0.2	58	N/A	N/A	18
Ramp down 2	0.1	19	N/A	N/A	18
Ramp down 2	0.02	3	N/A	N/A	18
Rampup 3	0.1	20	N/A	N/A	18
Rampup 3	0.2	56	N/A	N/A	18
Ramp down 3	0.1	19	N/A	N/A	18
Ramp down 3	0.02	3	N/A	N/A	18
Rampup 4	0.1	20	N/A	N/A	18

(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) Extremely nonuniform debris bed surface precluded these measurements for this test.
(c) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).

Table K.1.4. Preliminary Data for Test 060501_PQC_2609_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.)	
Bed formation	0.2	N/A	N/A	N/A	N/A
Rampup 1 (prefiltering)	0.2	N/A	N/A	N/A	N/A
Rampup 1 (post-filtering)	0.2	33	N/A	N/A	83
Ramp down 1	0.1	16	N/A	N/A	84
Ramp down 1	0.05	6	N/A	N/A	83
Ramp down 1	0.02	3	N/A	N/A	78
Rampup 2	0.1	12	N/A	N/A	82
Rampup 2	0.2	33	N/A	N/A	82
Ramp down 2	0.1	13	N/A	N/A	82
Ramp down 2	0.02	3	N/A	N/A	80
Rampup 3	0.1	13	N/A	N/A	84
Rampup 3	0.2	31	N/A	N/A	82
Ramp down 3	0.1	13	N/A	N/A	82
Ramp down 3	0.02	3	N/A	N/A	81
Rampup 4	0.1	13	N/A	N/A	84

(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) Extremely nonuniform debris bed surface precluded these measurements for this test.

Table K.1.5. Preliminary Data for Test 060504_PQZ_2609_LP1

Test Phase	Velocity (ft/sec)	Head Loss[a] (in. H_2O)	Manual Debris Bed Height Measurement[c]		Fluid Temperature (°C)
			Rim[b] (in.)	Estimated Body (in.)	
Bed formation	0.3	2[b]	N/A	N/A	20
Rampup 1	0.3	2	N/A	N/A	20
Rampup 1 (pre filtering)	0.7	16	N/A	N/A	21
Rampup 1 (post-filtering)	0.7	16	N/A	N/A	20
Ramp down 1	0.3	3	N/A	N/A	21
Ramp down 1	0.2	1	N/A	N/A	21
Ramp down 1	0.1	0.3	N/A	N/A	21
Ramp down 1	0.02	0.02	N/A	N/A	21
Rampup 2	0.1	0.3	N/A	N/A	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) Pressure measurement taken prior to increase of loop static pressure (~2.5 atm).
(c) Incomplete and extremely nonuniform debris bed surface precluded these measurements for this test.

Table K.1.6. Post-Retrieval Debris Bed Measurements, 060501_PQC_2609_LP1 and 060501_PQC_2609_LP2

Post-Retrieval Manual Debris Bed Measurements[a,b]			
Rim Height	Body Height	Total Bed Diameter	Body Diameter
N/A	0.04	6.06	N/A

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

Table K.1.7. Post-Retrieval Debris Bed Measurements, 060504_PQZ_2609_LP1

Post-Retrieval Manual Debris Bed Measurements[a,b]			
Rim Height	Body Height	Total Bed Diameter	Body Diameter
N/A	0.10	6.06	N/A

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

A Priority 5 ALK coating test in the benchtop loop (see *060428_PQC_1136_BP_Prel Rslts.doc*) was conducted prior to coatings tests in the large-scale loop. This test provided insight into debris loading, debris transport, and debris bed formation.

As reported, a debris bed was formed for the ALK coating Priority 5 test in the benchtop loop. Despite the small number of open channels observed, a head loss in excess of 100 in. H_2O was measured for an approach velocity of 0.20 ft/sec. Benchtop test conditions are reported in Table K.8 and preliminary test data in Table K.9. The test had a fluid temperature of nominally 21°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 the table; the benchtop loop test section inside diameter is 0.1016 m (4.0 in.).

Table K.1.8. Test Conditions, 060428_PQC_1136_BP1

Quick-Look report date	6/30/06
Date of test	4/28/06
Associated test case(s)	Series II Coating Priority 5
Test number and data file reference	060428_PQC_1136_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
Screen area (m^2)	0.0081
Target screen debris loading (g/m^2)	1450
Initial processed coating mass introduced (g)	5.68
Processed coating R4 target	1.4
Initial CalSil mass introduced (g)	5.68
1/4 in. coating R4 target	N/A
Debris loading sequence	Debris constituents premixed prior to introduction into the test loop
Initial bed formation screen approach velocity (ft/sec)	0.10[(a)]
Final bed formation screen approach velocity (ft/sec)	0.20
Bed formation time (min)	40
Calculated number of representative circulations during debris bed formation (from estimated 0.75-minute circulation time)	53
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)	6.18

(a) The initial screen approach velocity was set to 0.10 ft/sec as specified for the Series II tests; significant settling of the debris was observed and << 5% of the debris was visually observed to be on the plate. Tee velocity was ramped up; some mobilization of the settled debris was observed at 0.16 ft/sec. The screen approach velocity was then set to the maximum velocity of the test plan, 0.20 ft/sec, for the remainder of the bed formation period. The horizontal flow regions of the test loop were tapped with a rubber hammer until limited additional debris was observed to be mobilized. Subsequently, no ¼-in. debris was observed in the clear portions of the test loop (suggesting it was all retained on the plate); processed debris was observed to resettle.

Table K.1.9. Preliminary Data, 060510_CO_1469_BP1

Test Phase	**Velocity** (ft/sec)	**Head Loss** (in. H_2O)
Bed formation	0.20	108
Ramp down 1	0.10	29
Ramp down 1	0.05	12
Rampup 2	0.10	32
Rampup 2	0.20	90
Ramp down 2	0.10	26
Ramp down 2	0.05	11
Rampup 3	0.10	29

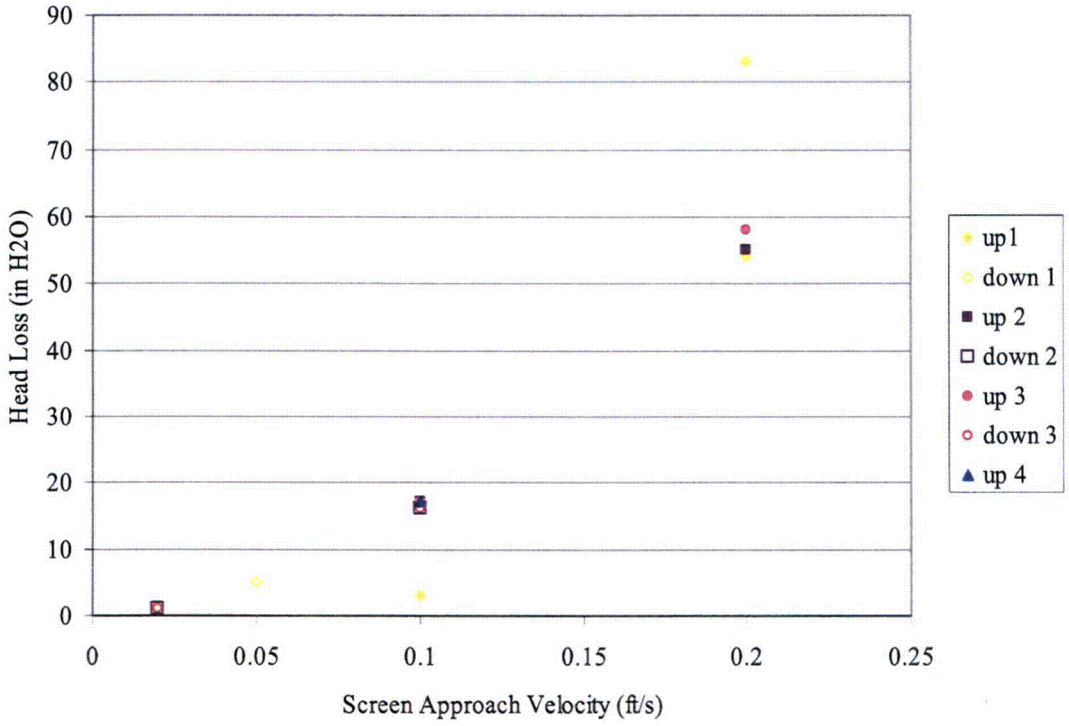


Figure K.1.1. Preliminary PNNL Data; 060501_PQC_2609_LP1

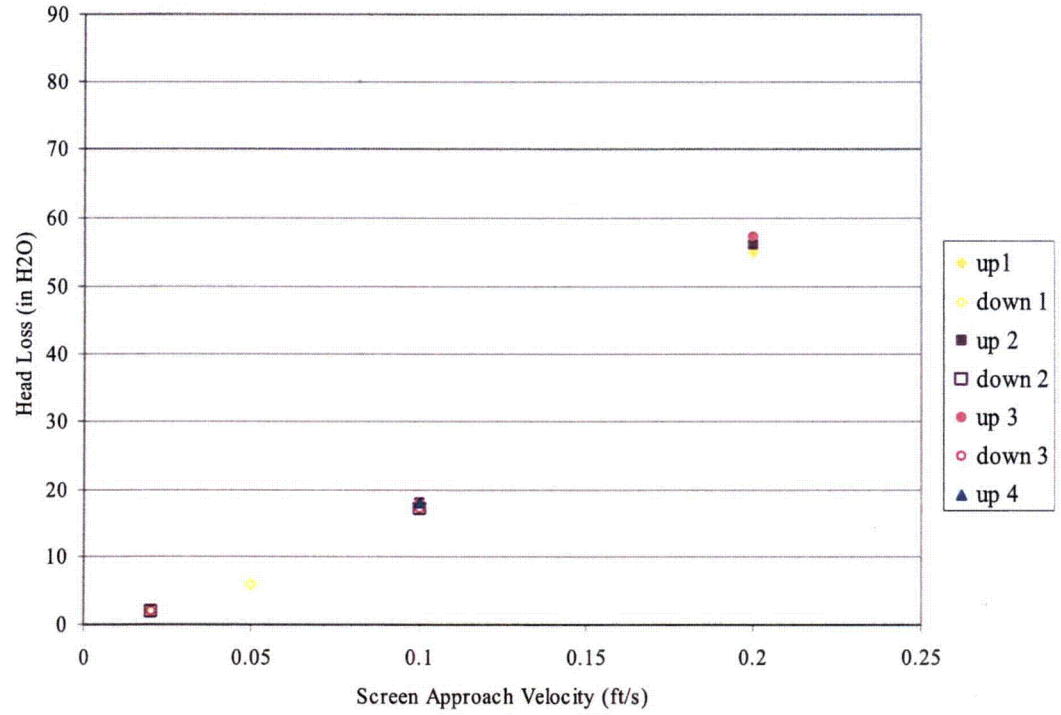


Figure K.1.2. Preliminary PNNL Data; 060501_PQC_2609_LP2

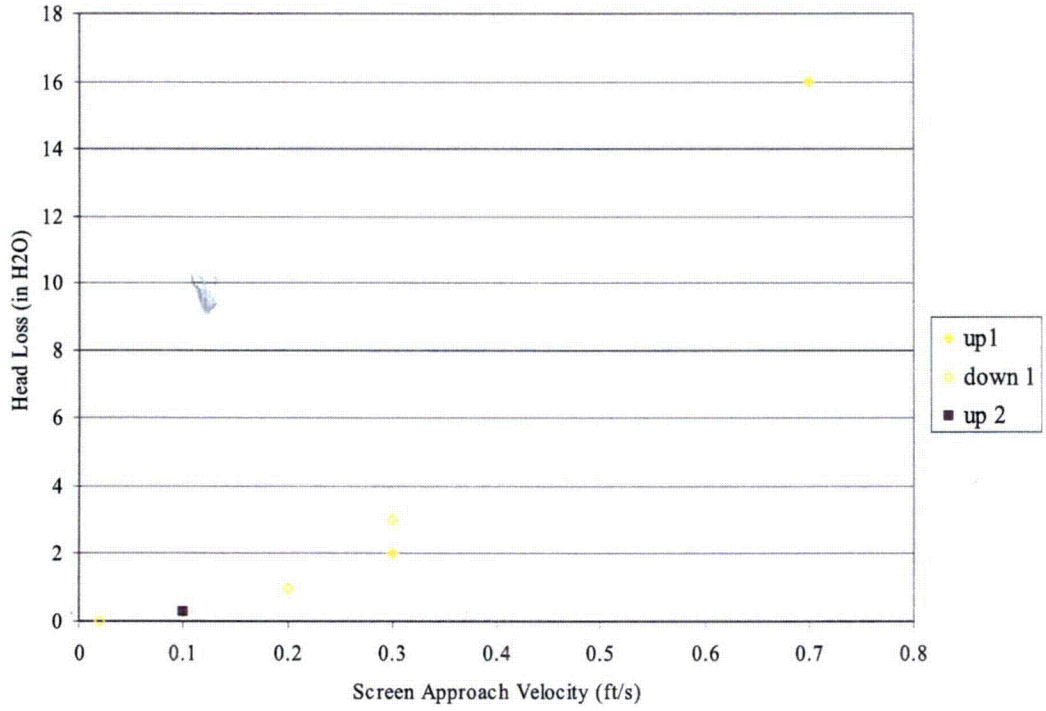


Figure K.1.3. Preliminary PNNL Data; 060504_PQZ_2609_LP1

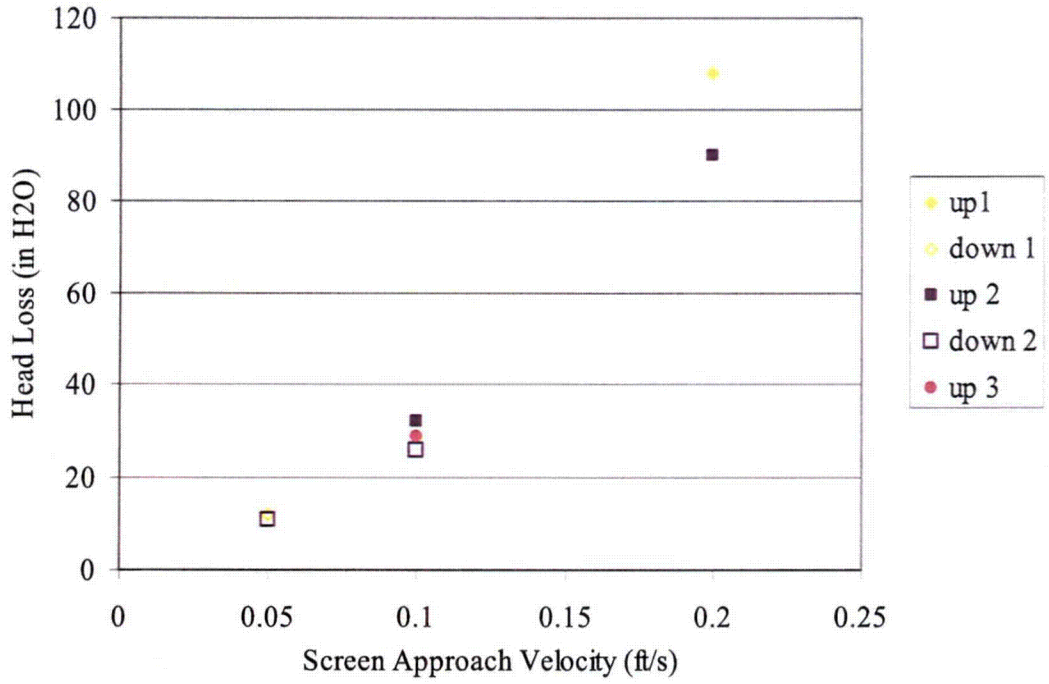


Figure K.1.4. Preliminary PNNL Data, 060428_PQC_1136_BP1, Bench Top Loop

Figure K.1.5. 060501_PQC_2609_LP1, LP2 Debris Bed in Test Section After Retrieval, Top View

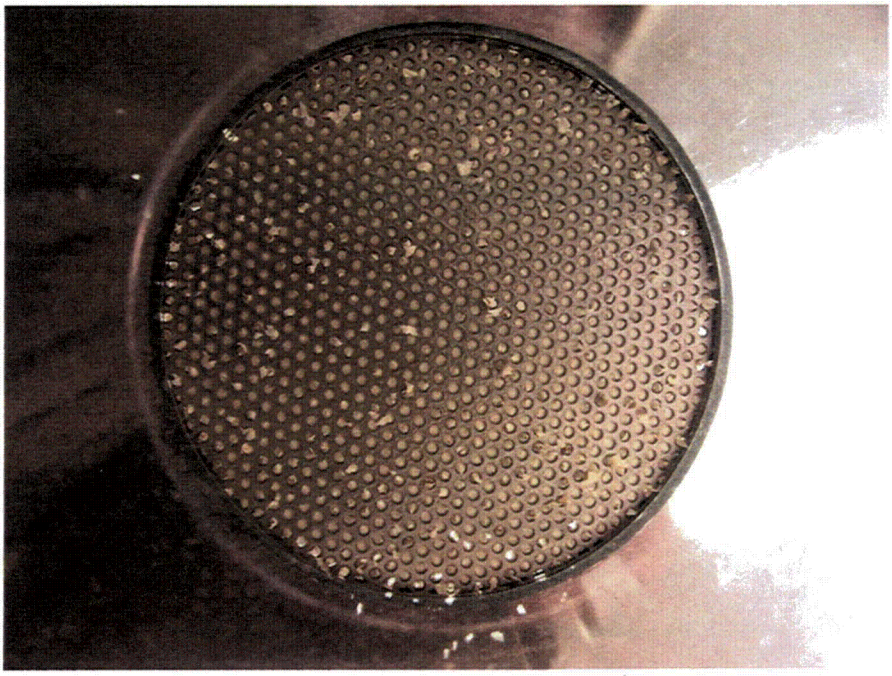


Figure K.1.6. 060501_PQC_2609_LP1, LP2 Debris Bed in Test Section After Retrieval, Bottom View (note penetration of ALK debris into perforations of plate)

Figure K.1.7. 060501_PQC_2609_LP1, LP2 Debris Bed After Retrieval from Test Section, Top View

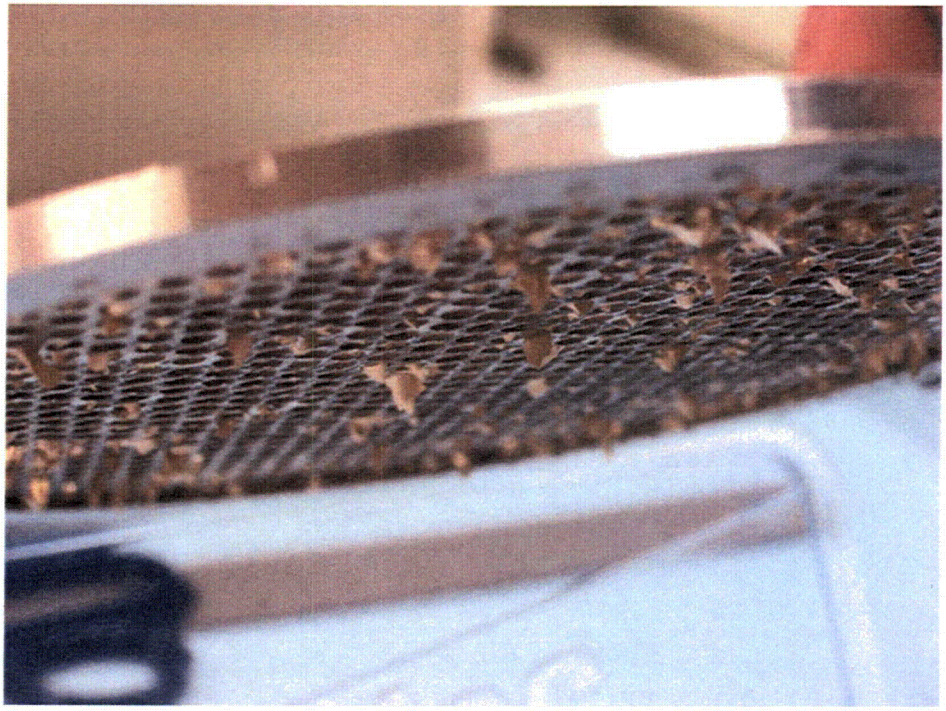


Figure K.1.8. 060501_PQC_2609_LP1, LP2 Debris Bed After Retrieval from Test Section, Bottom View from Edge (detail of penetration of ALK debris into perforations of plate)

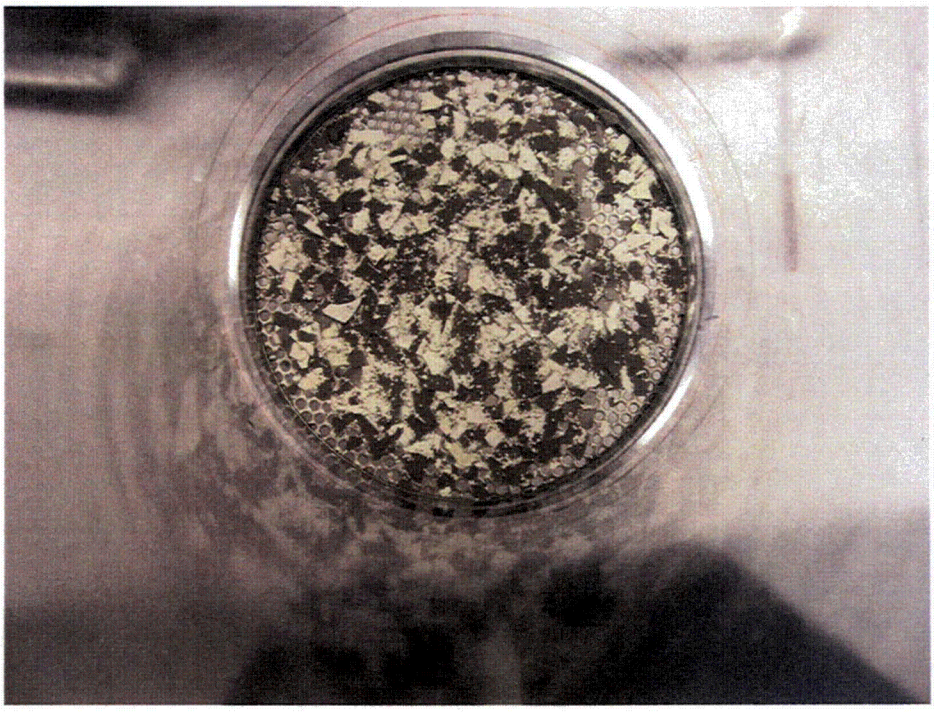


Figure K.1.9. 060504_PQZ_2609_LP1 Debris Bed in Test Section After Retrieval, Top View

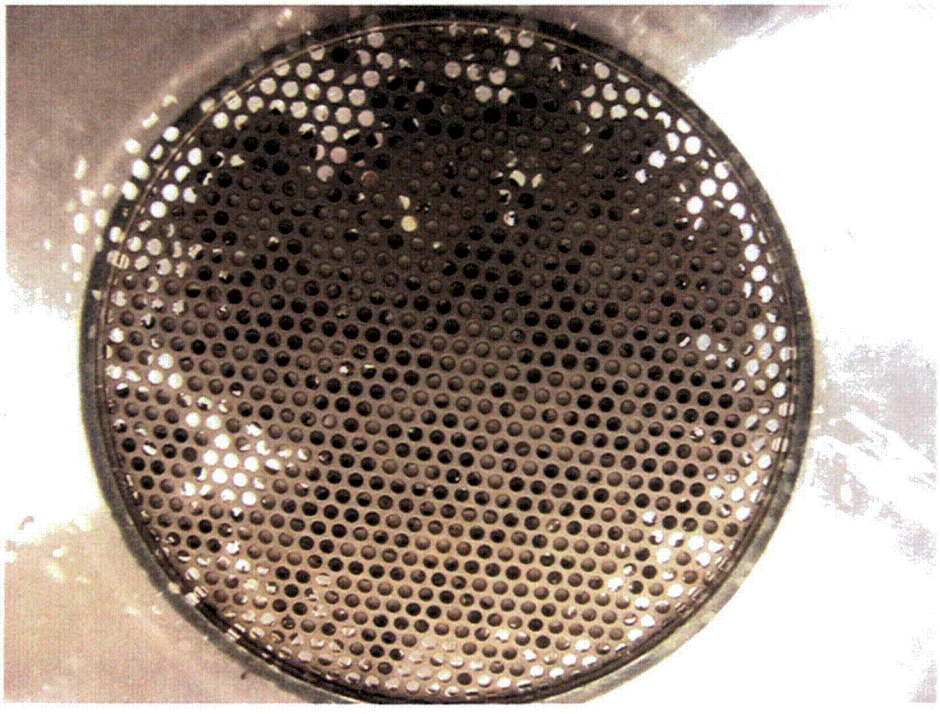


Figure K.1.10. 060504_PQZ_2609_LP1 Debris Bed in Test Section After Retrieval, Bottom View

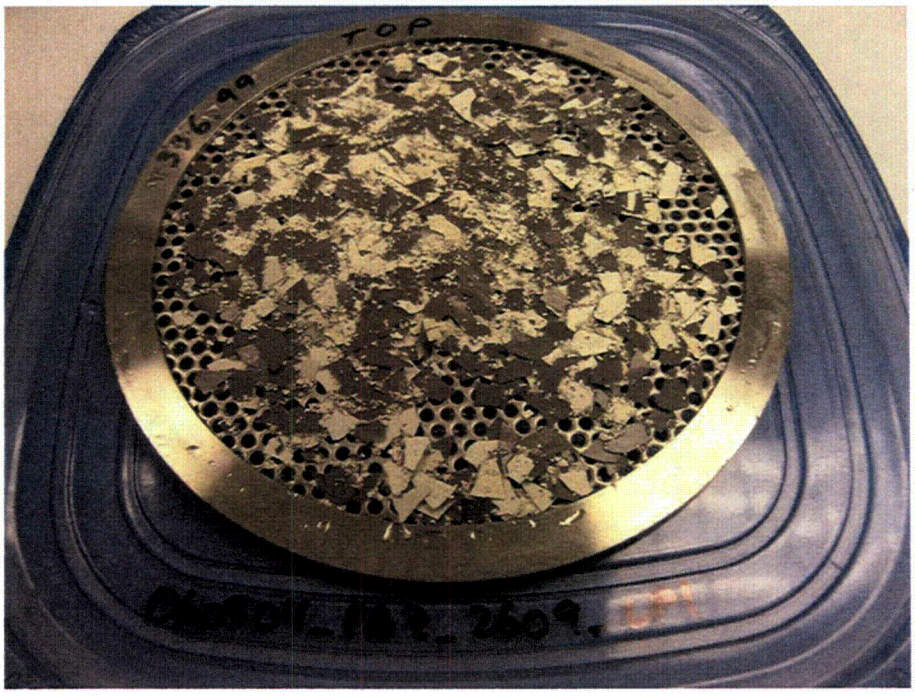


Figure K.1.11. 060504_PQZ_2609_LP1 Debris Bed After Retrieval from Test Section, Top View

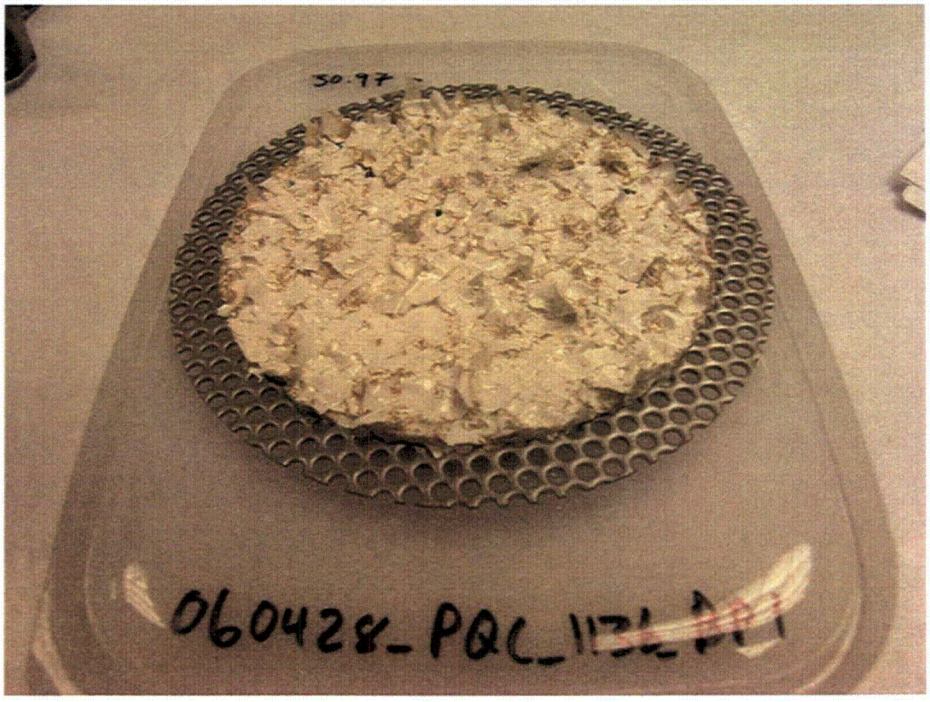


Figure K.1.12. 060428_PQC_1136_BP1 Debris Bed Post-Retrieval

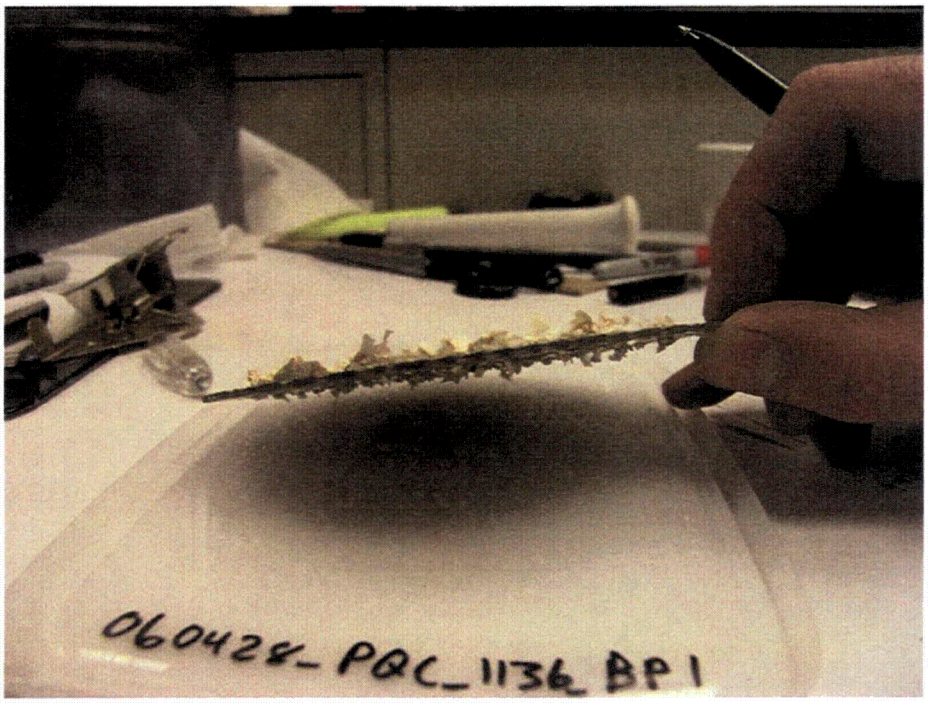


Figure K.1.13. 060428_PQC_1136_BP1 Debris Bed Post-Retrieval, Edge View (note penetration of ALK debris into perforations of plate)

Appendix L – Test Plan for Comparison Benchmark Testing of PNNL and ANL Test Loops Used to Measure Debris Bed Head Loss for Reactor Sump Pump Screens

Appendix L – Test Plan for Comparison Benchmark Testing of PNNL and ANL Test Loops Used to Measure Debris Bed Head Loss for Reactor Sump Pump Screens

CW Enderlin and BE Wells
Updated: 2/10/06
Filename: 060210 benchmark test plan rev0

In support of the NRC effort to resolve GSI 191, closed system test loops have been constructed at the Pacific Northwest National Laboratory (PNNL) and Argonne National Laboratory (ANL). The test loops have test sections containing sump pump screen material aligned perpendicular to the flow. Debris material is introduced into the flow stream and retained in the test section on the sump pump screen material forming a debris bed. The resulting head loss across the debris bed is measured as a function of screen approach velocity.

The ANL loop is intended to focus on evaluating the effects on debris bed head loss resulting from reactor containment chemistry changing the flow resistance of the bed. The PNNL test loop is intended to focus on investigating how physical effects associated with varying the ratio of debris constituents and the manner in which the constituents are applied to the screen impact the head loss. These two tests loops are being used to meet the schedule demands of the program. To justify the use of data from both test loops in developing head loss correlations for the debris beds, the NRC has proposed benchmarking the loops against each other. This test plan defines the initial effort being conducted to obtain comparative data from the two loops.

L.1 Objective

The objective of the tests is to benchmark the test loops against each other by comparing head loss measurements as a function of screen approach velocity, debris bed dimensions, and post-test debris mass measurements. These benchmark tests will allow for the comparison of the debris injection processes and measurement systems for the two loops. The debris material preparation and the debris bed formation process will be duplicated, as much as possible, to accomplish this.

L.2 Background

The following items are issues that have been considered in selecting the benchmark test cases and for determining the test conditions that need to be defined in an attempt to ensure the initial conditions are the same in each test loop:

- Both the ANL and PNNL test loops have 6-in. diameter test sections.
- The maximum head loss across the debris bed that can be measured is 165 and 2700 inches H_2O for the ANL and PNNL loops, respectively.
- The method of introducing the debris material into the test loop is different for each test loop.
- Testing conducted by PNNL has demonstrated that the degree of debris preparation for the NUKON debris material impacts the head loss of a debris bed. A metric (referred to as R4, see

Section L.4.1.1) and associated method of evaluation have been developed for assessing the degree of NUKON preparation.

- For debris beds containing both CalSil and NUKON, preliminary testing conducted to date by PNNL indicates that the loading sequence of the debris constituents can have a significant impact on the measured head loss for the resulting debris bed.
- PNNL test results conducted in the bench top loop indicated that repeatable results were obtained for CalSil-NUKON debris beds having a CalSil to NUKON mass ratio of approximately 0.2. Significant variations in measured head loss, in both the large-scale and bench top loops, were obtained for debris beds having a CalSil to NUKON mass ratio of 0.5. The variation in the results for the higher mass ratios is still being investigated.
- Test 050803_NO_0682_2 conducted in the PNNL bench top loop consisted of a NUKON debris bed with a target mass loading of 0.035 lbm/ft$_2$ (0.841 kg/m^2) and an R4 of approximately 11. Head loss measurements of approximately 14 and 124 inches H_2O were obtained for screen approach velocities of 0.16 and 0.65 ft/s respectively.
- Test 051004_NC_1469_1 conducted in the PNNL bench top loop consisted of a NUKON and CalSil debris bed with a total target mass loading of 0.076 lbm/ft^2 (1.812 kg/m^2). The NUKON target mass loading was 0.061 lbm/ft^2 (1.449 kg/m^2) with an R4 of approximately 11. The CalSil target mass loading was 0.015 lbm/ft^2 (0.363 kg/m^2), for a CalSil to NUKON mass ratio of 0.25. Head loss measurements of approximately 280 and 504 inches H_2O were obtained for screen approach velocities of 0.15 ft/s and 0.25 ft/s, respectively.
- ANL testing indicates the resulting head loss measurements have been more stable when the screen approach velocity is decreased following debris bed formation as opposed to increasing the approach velocity following bed formation. When the approach velocity is decreased from that initially used to generate a debris bed, ANL has obtained steady state pressure drops very quickly compared to the time duration required when the velocity is increased.
- The bulk of ANL testing has been conducted taking head loss measurements for approach velocities in the range of 0.02 to 0.1 ft/s. The bulk of the ANL debris beds have bed formed at an approach velocity of 0.1 ft/s followed by incrementally ramping down the approach velocity.
- The PNNL testing has been conducted taking head loss measurements over the range of approximately 0.02 to 1.0 ft/s with the bulk of the measurements taken between 0.1 to 0.4 ft/s. Debris beds have been generated in the PNNL large scale test loop at approach velocities of 0.1 and 0.2 ft/s followed by incrementally ramping up the approach velocity.
- PNNL has formed the debris beds with the fluid temperature at approximately 20°C (68°F). The PNNL loop in its current configuration is designed to introduce the debris material at a fluid temperature ≤ 40°C (104°F).

L.3 Test Matrix

The test cases were selected from the proposed test matrix, dated 12/1/05, WJ Krotiuk prepared for the Series II tests to be conducted at PNNL. The test cases were selected based on the following objectives/criteria.

- Test two NUKON-only cases and one NUKON/CalSil case.

- The NUKON cases should consist of a relatively thin bed (app 0.04 lb/ft^2 [0.2 kg/m^2]) and a relatively medium bed (app 0.16 lb/ft^2 [0.8 kg/m^2]).
- The NUKON/CalSil case will use the same NUKON mass loading as one of the two NUKON-only cases to reduce variations in debris preparation process between debris beds.
- The CalSil/NUKON ratio should be ≤ 0.25.
- Only cases that have an anticipated head loss ≤ 160 inches H_2O at an approach velocity of 0.2 ft/s should be selected to ensure head loss data can be obtained over a one order of magnitude range of approach velocities in both test loops.

Based on the background information presented in Section L.2 and the previously defined selection criteria, the three cases presented in Table L.3.1 have been selected for the benchmark tests. Each test case will be conducted once and results submitted to the NRC for evaluation and direction on performing repeat tests for selected test cases.

Table L.3.1. Benchmark Test Cases for ANL and PNNL Test Loops

Case No.	NUKON Mass Loading lb/ft^2 (kg/m^2)	CalSil Mass Loading lb/ft^2 (kg/m^2)	Total Mass Loading lb/ft^2 (kg/m^2)	CalSil to NUKON Mass Ratio
BM-1	0.044 (0.217)	0.0 (0.0)	0.044 (0.217)	0.0
BM-2	0.148 (0.724)	0.0 (0.0)	0.148 (0.724)	0.0
BM-3	0.148 (0.724)	0.030 (0.145)	0.178 (0.869)	0.2

L.4 Test Preparation

The test preparation is specified in an attempt to control the initial conditions at which the debris bed is formed on the screen. Test preparation consists of the test loop conditions, the preparation of the debris material, and the conditions at which the debris bed is formed. The system and method by which the debris material is physically introduced into the test loop will not be specified and is part of the conditions being qualified by these benchmark tests. Section L.4.1 summarizes how the debris material will be prepared prior to introduction. The test loop conditions at the start of testing are discussed in Section L.4.2, and the parameters specifications for bed formation are presented in Section L.4.3.

L.4.1 Debris Preparation

The CalSil and NUKON debris material to be used for the tests will be from the following sources:

- The NUKON material will come from Vendor/Manufacturer: Performance Contracting Inc., Lot No.: 09/06/5ND5, BS-4813 shipped: Oct. 8, 2005. This material was subjected to a 12 to 24 hr heat-treating process and shredded by the vendor/manufacturer prior to shipment.
- The CalSil material will come from Vendor/Manufacturer: Johns Manville, Lot No.: 017-276, BS-4823, shipped: September 28, 2005. The received CalSil material will be in the form of 3-in. by 12-in. by 48-in blocks. The CalSil material has not been subjected to any heat-treating process.

The preparation of the NUKON and CalSil materials is discussed in Sections L.4.1.1 and L.4.1.2, respectively.

L.4.1.1 NUKON Preparation

The debris preparation method for the NUKON used in the benchmark tests will be characterized by the R4 metric and the debris dilution used for blending. The R4 metric is defined by

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

The as-received "shredded" NUKON will be added to a specified volume of water and blended using an industrial bench top blender to separate/breakdown (i.e. "reduce") the fibrous material. The degree of blending and the amount of dilution for each test case will be obtained from trying to replicate the degree of material "reduction" performed by ANL for their most recent tests.

During past work at LANL the shredded NUKON fiber was boiled for duration of 10 to 15 minutes prior to being introduced to the loop. The boiling was performed to break down organic binders. ANL currently subjects the debris material to a "pre-soak," which consists of soaking the material in 140°F water for 30 minutes prior to introduction into the loop. The 30-min. pre-soak is intended to simulate the approx. 30 min. delay that would exist between the occurrence of a LOCA and the start of the circulation pump. To eliminate a potential source of variability, not "pre-soak" or boiling of the NUKON will be performed for the benchmark tests.

To determine the R4 metric, ANL will carry out their NUKON preparation method a minimum of three times for each of the NUKON mass loadings specified in Table L.3.1. The preparation method will use a constant NUKON mass and water volume for each batch and sub-batch of material generated.

Definition: Debris batch – The entire mass of a debris constituent that needs to be prepared to conduct a specific test. Example: Test case BM-2 requires 13.22 g of NUKON be introduced to the loop, therefore, the "batch" of NUKON for a test run for Case BM-2 is 13.22 g.

Definition: Debris sub-batch – The amount of mass that is to be placed in a single mixer for blending that is to be combined with other sub-batches to generate a single debris batch for testing. If the entire mass of a debris batch can be prepared in a single operation of the blender then no debris sub-batches are necessary.

The generation of a debris batch using sub-batches should attempt to use uniform sub-batches. Example: Suppose the required debris batch has a mass of 45 g, and the blender to be used can hold 500 ml of water and concentrations up to 30 g NUKON in 500 ml water can successfully be blended. A blend time and dilution rate should be determined for preparing three debris sub-batches of 15 g each. It would not be desirable to prepare two sub-batches of 20 g each using a specified dilution rate and blend time and then prepare a third sub-batch of 5 g using a second dilution rate and blend time.

Based on previous work conducted by LANL, the maximum concentration to be used for blending sub-batches of NUKON is 25g NUKON per1000 ml water.

After ANL prepares each debris sub-batch intended for the purpose of determining R4, an R4 test will immediately be conducted to determine the wet mass of material retained on the screen. The mass of NUKON retained on the screen will be photographed after each R4 test. The R4 tests will be conducted using 5-mesh screen. For each quantity of NUKON specified in Table L.3.1, the following information will be transmitted to PNNL:

- Individual R4 values calculated by ANL
- Dimensions of the 5-mesh screen used to conduct the R4 test
- The volume or mass of water used to generate a debris batch/sub-batch
- The mass of dry NUKON used to generate a debris batch/sub-batch
- Blender make and model number
- Photographs of the retained mass on the screen taken following each R4 test.

Note L.4.1.1–A: The debris material used to conduct an R4 test will never be introduced to the test loop. Once the dilution ratio and blend times have been determined and assessed via multiple R4 tests, the debris preparation procedure is executed to generate a debris batch for introduction into the loop. This prepared debris batch does not undergo an R4 test.

Note L.4.1.1–B: The retained mass on a screen following an R4 test is to be removed prior to executing a new R4 test.

PNNL will attempt to use the same dilution ratios as ANL and determine blending times required to achieve an average R4 value of within ±1 of the average ANL value for each quantity of NUKON required for the debris loadings specified in Table L.3.1. Conducting R4 tests on a minimum of three debris batch preparations will assess the final R4 value for the PNNL tests.

L.4.1.2 CalSil Preparation

The CalSil will be prepared by mortar and pestle on the dry debris material. The CalSil will be ground until no visible large particles exist. The final product should have the CalSil material disassociated from the fibrous component and the ground material should have the consistency of flour. Based on past observations by LANL it is recommended that relatively small sub-batches of CalSil should be ground separately to achieve the desired consistency. LANL observed that the separated fiber might tend to aggregate during continued grinding.

The dry ground material (including both the fiber and particulate) will then be added to water and blended in the blender. The dilution ratio of the dry CalSil and the blending time will be the same as that currently employed by ANL.

No "presoak" or boiling of the CalSil will be performed for the benchmark tests.

ANL will provide PNNL with the following:

- Photographs of the dry CalSil material following grinding using mortar and pestle.
- The dilution ratio of CalSil to water used for blending operations.

- The blending time used for a CalSil debris batch/sub-batch.
- Blender make and model number.
- A physical description of the appearance and pour ability of the CalSil slurry following blender operations.
- Photographs of the CalSil slurry.

PNNL will perform PSDA on a CalSil slurry prepared according to the final CalSil preparation procedure used for the benchmark tests.

L.4.1.3 Debris Preparation for Introduction to Loop

Following the preparation of the concentrated debris slurries discussed in Sections L.4.1.1 and L.4.1.2, there are three imposed debris preparation requirements for introduction of the debris material into the loop. This portion of the process is unique to the individual test loops and is being assessed by these benchmark tests. The three requirements are:

- The CalSil and NUKON materials are to be pre-mixed by manual stirring with a kitchen utensil prior to introduction into the test loop.
- The concentrated CalSil and NUKON slurries are to be prepared just prior to testing.
- The prepared, mixed slurry is to continually experience some form of mild agitation to prevent material settling and agglomeration prior to introduction into the test loop. Past experience has demonstrated that manual stirring with a kitchen utensil is sufficient.

L.4.2 Test Loop Conditions

The test loops will use perforated plate as the sump pump screen aligned in a horizontal orientation perpendicular to the flow in a vertical test section. The perforated plate will have the dimensions specified in Table L.4.1. Due to the manufacturing process, the holes in the perforated plate will have a squared edge and a rounded edge. The plate is to be installed with the rounded edges of the holes directed upstream.

Table L.4.1. Perforated Plate Dimensions

Diameter of Perforations (in.)	Center to-Center Pitch (in.)	Hole Pattern	Percent Open Area (%)	Plate Thickness (in.)
1/8	3/16	Staggered 60° centerline pattern	40	0.056

The test loop is to be flushed and inspected (based on past practices and assessments made for the individual loops) to ensure minimal residual free debris material exists from past testing.

The loop is to be filled with DI water for testing. Degassing of the water should be conducted to minimize/eliminate the presence of gas in the system during testing.

L.4.3 Debris Bed Formation

The diluted, premixed debris slurry is to be continually agitated prior to introduction into the loop as specified in Section L.4.1.3. The debris slurry is to be introduced into the test loop with the screen

approach velocity adjusted to 0.1 ft/s. The approach velocity is defined as the average velocity in the upstream test section. The retention of debris material on the test screen will cause a change in the system curve for the test loop resulting in an increase in pressure drop across the debris bed and a corresponding reduction in screen approach velocity. During debris bed formation the screen approach velocity is to be maintained between 0.09 and 0.1 ft/s.

The fluid temperature during bed formation and for the duration of the test is to be maintained at 25°± 5°C (77° ± 9°F).

The indicated head loss is to be sampled at a minimum frequency of 0.5 Hz and monitored with a running 1-minute average of the sampled data. The head loss data is to be logged at a minimum frequency of 0.1 Hz. The debris bed formation process will be considered complete when both of the following two criteria have been satisfied.

1. A minimum time equivalent to 20 calculated loop circulations assuming a constant screen approach velocity of 0.1 ft/s has elapsed.
2. The absolute change in head loss based on a 1-minute running average is less than 2% over 10 minutes. The criteria will be assessed and satisfied three times. The minimum time between assessments will be one minute. The criteria is expressed as

$$0.02 \geq \left| \frac{\Delta P_{t_1} - \Delta P_{t_2}}{\Delta P_{t_1}} \right|$$

where

ΔP_{t1} = the measured head loss across the bed at time t_1.
ΔP_{t2} = the measured head loss across the bed at time t_2.
$t_1 - t_2 \geq 10$ minutes

Exception: For head loss measurements less than 14 inches H_2O (0.5 psi) the acceptance criteria will be:

$$0.05 \geq \left| \frac{\Delta P_{t_1} - \Delta P_{t_2}}{\Delta P_{t_1}} \right|$$

At the completion of bed formation the following will be recorded:

- • Photographs of the debris bed
- • Measurements of the debris bed thickness
- • Time duration between debris introduction and steady state head loss readings.

L.5 Testing & Measurements

The actual testing is considered to commence after the debris bed has been formed (data will be taken over the entire test period including static loop conditions, flow initialization, bed formation, etc.). The objective of the items discussed in Section L.4 is to generate a debris bed in each loop for a given test case that is similar. This section defines the success criteria for the benchmark tests in Section L.5.1,

presents current issues associated with the test plan in Section L.5.2, outlines the test process in Section L.5.3, and discusses post test measurements in Section L.5.4,

L.5.1 Success Criteria

The success criteria for this test plan is to obtain, from both ANL and PNNL, data from one test for each test condition listed in Table L.3.1. The data is to include head loss measurements for the velocity sequence presented in Table L.5.1. The steady state head loss measurements and post-test debris bed measurements will be used to compare the measurement and debris injection systems for both loops. Following the initial comparison of the test results, the NRC will determine if additional testing is required under this test plan.

L.5.1.1 Discussion of Success Criteria

Disregarding experimental uncertainty associated with carrying out the test preparation tasks, the differences between debris beds generated in the two loops should be the result of random variation associated with the debris bed formation process and the differences in the debris injection methods. The random variation associated with debris bed formation can be investigated with repeat tests in the individual test loops. The variations due to the physical debris loading process may only be distinguishable at small velocities (≤ the bed formation velocity) and may be eliminated with exposure to higher velocities.

It is plausible that differences, which exist immediately following bed formation, between the debris beds generated in the two tests loops will be eliminated or reduced as a result of subjecting the debris bed to velocity cycling or increased pressure drop. Therefore, the two test loops may yield different measurements of head loss until a threshold pressure drop is achieved, and then display acceptable agreement. No definition has been given for acceptable benchmarking. Example: Has successful benchmarking been achieved if it requires five velocity cycles or testing at velocities greater than 0.2 ft/s to achieve good agreement between the two test loops?

No criteria have been given for the repeatability requirements of an individual test loop.

L.5.1.2 Potential Success Criteria for the Benchmark Tests

- Complete one test in both the ANL and PNNL test loops for each test case (refer to Table L.3.1).
- Obtain average steady state measurements as a function of approach velocity for the two test loops that are within 10 % of each other after two cycles of velocity ramp up and down.

L.5.2 Test Plan Issues

This section presents several issues that should be considered in determining whether the current test plan is sufficient to meet the stated objectives and the project needs. The issues are also items that should be considered when comparing the measurements obtained from the two loops.

The current test plan calls for generating the debris beds at a screen approach velocity of 0.1 ft/s (0.030 m/s). During Series I testing at PNNL it appeared that debris settled within the loop during the debris formation process. This settled material appeared to be resuspended at higher velocities later

during the test. If settling of debris material occurs, then the debris beds may vary in mass for the initial test measurements until material is potentially resuspended at a higher velocity and deposited on the debris bed. The material may not be resuspended since the critical velocity to sustain suspension for a given material at a specific concentration can be lower than the critical velocity for resuspension. If variations in the results are encountered between the two test loops and a discrepancy is observed in the post-test debris bed mass measurements, it is recommended that consideration be given to repeating the test case with a greater debris bed formation velocity.

The inventory of the PNNL test loop is approximately twice that of the ANL loop. The potential for this difference between the test loops to create significant differences in head loss measurements is considered minimal as long as debris material does not settle during the bed formation process. The following issues should be considered when comparing test results from the two loops.

- If material settles during bed formation, at increased velocities the addition of debris to the retained debris bed could be expected to occur at twice the rate in the ANL loop. This effect could explain the observation of results being comparable at lower velocities and then deviating at higher velocities (at least for the first velocity ramp-up at velocities greater than the bed formation velocity).
- The debris bed in the PNNL loop will be subjected to flow for a longer period of time to obtain a similar retained mass as in the ANL loop.

It is recommended by PNNL that the test program should not rely on obtaining pressure drop data for screen approach velocities in the transition flow regime (refer to memo from CW Enderlin to WJ Krotiuk dated 5/19/05). The current velocity sequence presented in Section L.5.3, Table L.5.1 has head loss measurements being taken at steady state velocities predicted to create a transition flow in the test section. At a temperature of 210°C (70°F), the transition flow regime is predicted to exist for screen approach velocities from 0.009 to 0.026 m/s (0.031 to 0.085 ft/s). At a temperature of 93°C (140°F), the transition flow regime is predicted to exist for screen approach velocities from 0.005 to 0.012 m/s (0.015 to 0.041 ft/s). It is recommended that the head loss measurements be taken for the entire velocity sequence, but the potential flow regime issue should be considered when comparing test results between the two loops.

L.5.3 Test Process

After the debris bed has been formed and the criteria for steady state conditions met, the bed will be subjected to a sequence of velocities that are listed in Table L.5.1. Each approach velocity will be maintained until a steady state head loss has been achieved. A steady state head loss will be assumed after all of the following three requirements have been met:

Table L.5.1. Velocity Sequence for the ANL and PNNL Test Loop Benchmark Cases

Test Point	Velocity (ft/sec)	Test Sequence
Initial condition	0.10	Bed Formation
1	0.10	Ramp down 1
2	0.05	Ramp down 1
3	0.02	Ramp down 1
4	0.05	Ramp up 1

Table L.5.1. (contd)

Test Point	Velocity (ft/sec)	Test Sequence
5	0.10	Ramp up 1
6	0.05	Ramp down 2
7	0.02	Ramp down 2
8	0.10	Ramp up 2
9	0.15	Ramp up 2
10	0.20	Ramp up 2
11	0.15	Ramp down 3
12	0.10	Ramp down 3
13	0.15	Ramp up 3
14	0.20	Ramp up 3
15	0.10	Ramp down 4
16	0.05	Ramp down 4
17	0.02	Ramp down 4
18	0.10	Ramp up 4

1. The steady state velocity has been maintained for a minimum of 5 minutes.
2. If the current velocity is the peak velocity at the end of a ramp up, then the steady state velocity has been maintained for a minimum of 10 minutes.
3. The absolute change in head loss based on a 1-minute running average is less than 2% over 5 minutes. (Exception: For head loss measurements less than 14 inches H_2O (0.5 psi), the absolute change in head loss based on a 1-minute running average will be less than 5% over 5 minutes). The criteria will be assessed and satisfied three times. The minimum time between assessments will be one minute.

The fluid temperature during testing is to be maintained at 25° ± 5°C (77° ± 9°F). The velocity test matrix/sequence to be performed is presented in Table L.5.1.

If ANL obtains head losses greater than 160 inches H_2O for any test case, a velocity, which yields a head loss between 150 to 160 inches H_2O, will be substituted, for the individual test case, for the peak velocity in Table L.5.1. The revised velocity sequence for the specified test case will be transmitted to PNNL. After a steady state head loss has been achieved:

- The head loss across the debris bed and fluid velocity measurements will be recorded for a minimum of two minutes at a minimum of 0.1 Hz.
- The debris bed height will be measured
- The fluid temperature in the loop will be measured.

L.5.4 Post-Test Measurements

After the velocity sequence in Table L.5.1 has been executed the debris bed is to be retrieved for post-test analyses. Post-test measurements are to include:

- Debris bed height along two perpendicular diameters.
- The mass of the wet retrieved debris bed.

- The dry mass of the retrieved debris bed as a function of time demonstrating a constant mass has been achieved at an elevated temperature. PNNL currently dries the debris beds at 90°C and ambient pressure.

L.6 Deliverable

The preliminary test results for each individual test will be transmitted to the NRC in separate Quick-Look reports within 3 days after the post-test dry mass measurements of the debris bed are completed.

The final results will be incorporated in the final NUREG reports for the individual projects being conducted by PNNL and ANL.

Appendix M – Test Matrix of NUKON-only Tests Conducted in the Benchtop Test Loop

Appendix M – Test Matrix of NUKON-only Tests Conducted in the Benchtop Test Loop

Test Number and Data File Reference	Target NUKON Mass Introduced (g)	Target Screen Debris Loading (g/m^2)	Fluid Temp. (C)	Screen Material	NUKON R4 Target	Initial Bed Formation Screen Approach Velocity (ft/sec)	Final Bed Formation Screen Approach Velocity (ft/sec)	Dry Retrieved Debris Bed Mass (g)
071805_NO_1175_2	11.75	1449.5	N/A	5 mesh	No data	0.26	No data	9.42
071805_NO_1175_1	11.75	1449.5	19.6	5 mesh	No data	0.26	No data	11.18
072005_NO_1175_2	11.75	1449.5	20.4	5 mesh	No data	0.26	No data	10.34
072005_NO_1175_3	11.75	1449.5	22.6	5 mesh	No data	0.26	No data	No data
072105_NO_1175_1	11.75	1449.5	N/A	5 mesh	No data	N/A	No data	No data
072205_NO_1175_1	11.75	1449.5	27.4	5 mesh	No data	0.37	No data	No data
072205_NO_1175_2	11.75	1449.5	23.0	5 mesh	No data	0.26	No data	No data
072505_NO_1175_1	11.75	1449.5	N/A	5 mesh	No data	0.26	No data	No data
072505_NO_1175_2	11.75	1449.5	N/A	5 mesh	No data	0.19	No data	10.23
072505_NO_1175_3	11.75	1449.5	23.2	5 mesh	No data	0.19	No data	10.16
072705_NO_1175_1	11.75	1449.5	21.7	5 mesh	No data	0.13	No data	9.65
072705_NO_1175_2	11.75	1449.5	22.7	5 mesh	No data	0.06	No data	4.83
072705_NO_1175_3	11.75	1449.5	20.4	5 mesh	No data	0.08	No data	7.26
072705_NO_1175_4	11.75	1449.5	23.6	5 mesh	No data	0.10	No data	8.15
072805_NO_1175_1	11.75	1449.5	22.8	5 mesh	No data	0.11	No data	8.48
072805_NO_1175_2	11.75	1449.5	22.8	5 mesh	No data	0.14	No data	9.65
072905_NO_1175_1	11.75	1449.5	23.4	5 mesh	No data	0.15	No data	10.26
072905_NO_1175_2	11.75	1449.5	26.9	5 mesh	No data	0.15	No data	11.8
080105_NO_1175_1	11.75	1449.5	24.2	5 mesh	No data	0.16	No data	No data
080205_NO_1363_1	13.63	1681.4	49.3	5 mesh	No data	0.19	No data	15.07
080305_NO_1363_1	13.63	1681.4	25.9	5 mesh	No data	0.19	No data	13.5
080305_NO_0682_2	6.82	840.7	24.4	5 mesh	No data	0.19	No data	6.39
080405_NO_0176_1	1.76	217.4	22.5	5 mesh	10-12	0.19	No data	1.41
080405_NO_0087_2	0.87	107.3	N/A	5 mesh	10-12	0.19	No data	0.45
080505_NO_0087_1	0.87	107.3	N/A	5 mesh	10-12	0.19	No data	0.83
080505_NO_0176_2	1.76	217.4	N/A	5 mesh	10-12	0.19	No data	No data
080505_NO_0588_3	5.88	724.7	26.0	5 mesh	10-12	0.19	No data	No data
081105_NO_1363_1	13.63	1681.4	32.2	5 mesh	10-12	0.19	No data	13.93
081505_NO_1363_1	13.63	1681.4	33.0	5 mesh	10-12	0.19	No data	13.8
082205_NO_1175_1	11.75	1449.5	19.5	5 mesh	10-12	0.06	No data	10.61
083005_NO_1175_1	11.75	1449.5	N/A	5 mesh	No data	0.19	No data	8.44
090705_NO_1175_1	11.75	1449.5	20.2	5 mesh	No data	0.19	No data	No data
050909_NO_0588_1	5.88	724.7	22.0	5 mesh	10-12	0.20	0.18	No data
050909_NO_0176_2	1.76	217.4	21.6	5 mesh	10-12	0.19	0.19	No data
050912_NO_0588_1	5.88	724.7	20.9	5 mesh	10-12	0.19	0.18	5.02
050912_NO_0176_2	1.76	217.4	20.8	5 mesh	10-12	0.19	0.18	1.57
050915_NO_1363_1	13.63	1681.4	35.0	5 mesh	10-12	0.19	0.68	14.04
050916_NO_1363_1	13.63	1681.4	26.5	5 mesh	No mixing	0.19	0.17	13.66
051010_NO_1175_1	11.75	1449.5	21.2	5 mesh	No mixing (~19)	0.20	0.19	11.81
051010_NO_1175_2	11.75	1449.5	21.3	5 mesh	14.5	0.20	0.17	11.41
051010_NO_1175_3	11.75	1449.5	21.8	5 mesh	11.5	0.20	0.18	11.12
051010_NO_1175_4	11.75	1449.5	22.3	5 mesh	~9	0.20	0.18	10.55
051011_NO_1175_1	11.75	1449.5	22.6	5 mesh	No mixing (~19)	0.20	0.19	11.94
051011_NO_1175_2	11.75	1449.5	22.3	5 mesh	14.5	0.20	0.19	11.57
051013_NO_1175_1	11.75	1449.5	23.2	5 mesh	10-12	0.20	0.17	11.35
051013_NO_1175_2	11.75	1449.5	22.6	5 mesh	5.6	0.20	0.18	11.22

Test Number and Data File Reference	Target NUKON Mass Introduced (g)	Target Screen Debris Loading (g/m^2)	Fluid Temp. (C)	Screen Material	NUKON R4 Target	Initial Bed Formation Screen Approach Velocity (ft/sec)	Final Bed Formation Screen Approach Velocity (ft/sec)	Dry Retrieved Debris Bed Mass (g)
051017_NO_1175_1	11.75	1449.5	22.8	5 mesh	No mixing	0.20	0.19	11.88
051017_NO_1175_2	11.75	1449.5	24.3	5 mesh	16.4	0.20	0.18	11.54
051020_NO_1175_1	11.75	1449.5	21.7	5 mesh	13.3	0.20	0.17	11.48
051020_NO_1175_2	11.75	1449.5	23.9	5 mesh	16.4	0.20	0.18	11.25
051026_NO_0087_1	0.87	107.3	20.7	5 mesh	No mixing (20.3)	0.20	0.21	No data
051027_NO_0087_1	0.87	107.3	21.5	5 mesh	8.6	0.20	0.18	0.26
051220_NO_0087_B1	0.87	107.3	24.3	5 mesh	No mixing	0.20	0.94	0.92
051220_NO_0087_B2	0.87	107.3	24.5	5 mesh	No mixing	0.20	0.95	1.11
051221_NO_0087_B1	0.87	107.3	23.7	5 mesh	5-7	0.20	0.94	0.71
051221_NO_0087_B2	0.87	107.3	25.5	5 mesh	5-7	0.20	0.94	0.68
051222_NO_0087_B1	0.87	107.3	23.6	5 mesh	10-12	0.20	0.94	0.78
051222_NO_0087_B2	0.87	107.3	28.4	5 mesh	10-12	0.20	0.94	0.78
051222_NO_0087_B3	0.87	107.3	25.0	5 mesh	~15	0.20	0.94	0.85
051223_NO_0087_B1	0.87	107.3	26.9	5 mesh	~15	0.20	0.94	0.85
060106_NO_1363_B1	13.63	1681.4	27.8	5 mesh	10-12	0.20	0.78	No data
060110_NO_1363_B1	13.63	1681.4	29.6	5 mesh	10-12	0.20	0.75	No data
060119_NO_1363_B1	13.63	1681.4		5 mesh	10-12	0.20	0.45	No data
060202_NO_1363_B1	13.63	1681.4	26.3	5 mesh	10-12	0.20	0.19	13.56
060210_NO_1363_B1	13.63	1681.4	20.8	5 mesh	10-12	0.20	0.20	12.96
060216_NO_1363_BP2	13.63	1681.4		perforated plate	10-12	0.20	0.25	14.69
060217_NO_1363_BP1	13.63	1681.4		perforated plate	10-12	0.20	No Data	13.2
060223_NO_1363_B1	13.63	1681.4		5 mesh	10-12	0.20	0.88	13.45
060228_NO_1363_B1	13.63	1681.4		5 mesh	10-12	0.20	0.20	13.3
060228_NO_1363_BP2	13.63	1681.4		perforated plate	10-12	0.20	0.20	12.53
060302_NO_1363_BP1	13.63	1681.4		perforated plate	10-12	0.20	0.20	13.1
060324_NO_1363_BAP1	13.63	1681.4	29.0	perforated plate	10-12	0.20	0.20	14.03
060327_NO_1363_BAP1	13.63	1681.4	25.6	perforated plate	10-12	0.20	0.20	12.93
060328_NO_1363_BAP1	13.63	1681.4	27.0	perforated plate	10-12	0.20	0.20	12.81
060414_NO_1363_B1	13.63	1681.4	29.4	5 mesh	10-12	0.20	0.75	13.56
060418_NO_1363_B1	13.63	1681.4		5 mesh	10-12	0.20	0.75	13.23
060419_NO_1363_B1	13.63	1681.4		5 mesh	10-12	0.20	0.75	13.03
060421_NO_1363_BP1	13.63	1681.4	27.0	perforated plate	10-12	0.20	0.20	12.96
060523_NO_1363_BAP1	13.63	1681.4	29.0	perforated plate	10-12	0.20	0.20	16.59

Appendix N – Test Matrix of NUKON/CalSil Tests Conducted in the Benchtop Test Loop

Appendix N – Test Matrix of NUKON/CalSil Tests Conducted in the Benchtop Test Loop

Test Number and Data File Reference	Initial NUKON Mass Introduced (g)	Initial CalSil Mass Introduced (g)	Target Screen Debris Loading (g/m^2)	Fluid Temperature (C)	Screen Material	NUKON R4 Target	Initial Bed Formation Screen Approach Velocity (ft/sec)	Final Bed Formation Screen Approach Velocity (ft/sec)	Dry Retrieved Debris Bed Mass (g)
050831_NC_1763_1	11.75	7.88	N/A		5 mesh	N/A	0.20	0.114	15.55
050831_NC_1763_2	11.75	5.88	2174.2		5 mesh	N/A	0.20	0.003	N/A
050901_NC_1763_1	11.75	5.88	2174.2	22.3	5 mesh	N/A	0.21	0.064	15.58
050901_NC_1763_2	11.75	5.88	2174.2		5 mesh	N/A	0.21	N/A	14.5
050908_NC_1469_1	11.75	2.94	1811.9	22.1	5 mesh	N/A	0.20	0.179	13.02
050908_NC_1469_2	11.75	2.94	1811.9	19.9	5 mesh	N/A	0.20	0.191	13.11
050919_NC_1469_1	11.75	2.94	1811.9	23.2	5 mesh	10-12	0.20	0.163	13.15
051004_NC_1469_1	11.75	2.94	1811.9	25.0	5 mesh	10-12	0.20	0.148	13.61
051006_NC_1496_1	11.75	2.94	1811.9	25.1	5 mesh	10-12	0.20	0.140	13.68
051214_NC_1234_B1	8.23	4.11	1522.0	26.6	5 mesh	10-12	0.20	0.020	10.76
051214_NC_1234_B2	8.23	4.11	1522.0	26.3	5 mesh	10-12	0.20	0.045	10.17
051215_NC_1234_B1	8.23	4.11	1522.0	24.3	5 mesh	10-12	0.20	0.050	11.58
051215_NC_1234_B2	8.23	4.11	1522.0	24.2	5 mesh	10-12	0.20	0.050	11.42
051216_NC_1234_B1	8.23	4.11	1522.0	23.2	5 mesh	10-12	0.20	0.050	11.66
051227_CO_0411x_B1	0	17.63	2174.2	25.5	5 mesh	N/A	0.20	0.200	1.49
051227_CO_1763_B2	0	17.63	2174.2	N/A	5 mesh	N/A	0.20	0.200	2.26
051228_NC_1234_B1	8.23	4.11	1522.0	30.0	5 mesh	10-12	0.20	0.020	10.15
051228_NC_1234_B2	8.23	4.11	1522.0	31.0	5 mesh	10-12	0.20	0.016	10.33
051228_NC_1234_B3	8.23	4.11	1522.0	29.9	5 mesh	10-12	0.20	0.024	9.6
060207_NC_1234_B1	8.23	4.11	1522.0	N/A	5 mesh	10-12	0.20	0.005	9.3
060303_NC_1234_B1	8.23	4.11	1522.0	N/A	5 mesh	10-12	0.20	0.170	8.66
060303_NC_1234_B2	8.23	4.11	1522.0	N/A	5 mesh	10-12	0.20	0.006	9.44
060406_CO_1176_BP1	0	11.76		N/A	perforated plate	N/A	0.10	0.170	0.64
060516_NC_1234_B1	8.23	4.11	1522.0	32	5 mesh	10-12	0.20	0.070	
060519_NC_1234_B1	8.23	4.11	1522.0	29	5 mesh	10-12	0.20	0.034	
060522_NC_1234_BP1	8.23	4.11	1522.0	24	perforated plate	10-12	0.20	0.050	10.47

Appendix O – Particle Size Characterization Photos for ALK and ZE Coatings

Appendix O – Particle Size Characterization Photos for ALK and ZE Coatings

For each of the four coating debris tested; ALK-processed, ALK-Chips, ZE-processed, and ZE-chips, samples were prepared, arranged, and photographed. To arrange the coatings material the particles were spread onto a black background and manually spaced so that no particles were touching. The underside and topside of the ZE material are different colors so the particulate was arranged with a uniform colored side showing. Figures O.1.1 through O.1.4 contain the characterization photos for the ALK-processed, ALK-chips, ZE-processed, and ZE-chips debris, respectively.

The four photos were provided to the Naval Surface Warfare Center (NSWC) for size characterization using photo imaging and analysis software. The particle sizing software used for the analysis was developed by Jason Carneal of NSWC using Matlab® and was titled ChipSizer. Anne Fullerton of NSWC performed a two dimensional analysis of the photos to determined the maximum (major axis) and minimum (minor axis) dimensions for each particle pictured. Tables O.1.1 through O.1.4 provide tabular size distributions based on both the major and minor axes for the ALK-processed, ALK-chips, ZE-processed, and ZE-chip debris, respectively. The tables also provide the mass and particle count for each coating debris evaluated. Figures O.1.5 through O.1.8 are histograms of the particle distributions obtained for the ALK-processed, ALK-chips, ZE-processed, and ZE-chip debris, respectively.

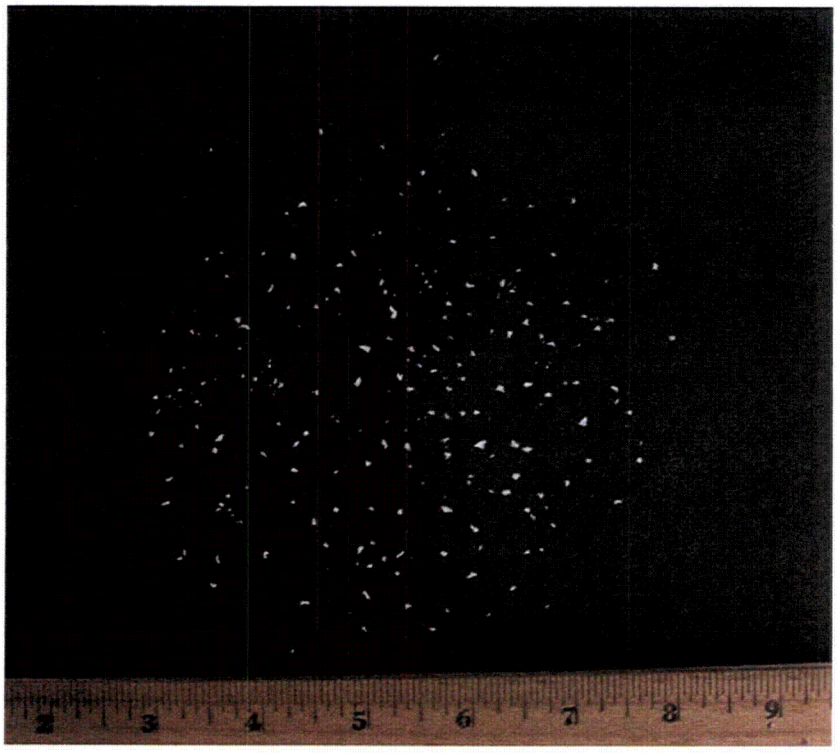


Figure O.1.1. Size Characterization Photo for ALK-Processed Debris. Total mass of particulate in photo was 0.01 g.

Figure O.1.2. Size Characterization Photo for ALK-Chips Debris. Total mass of particulate in photo was 0.17 g.

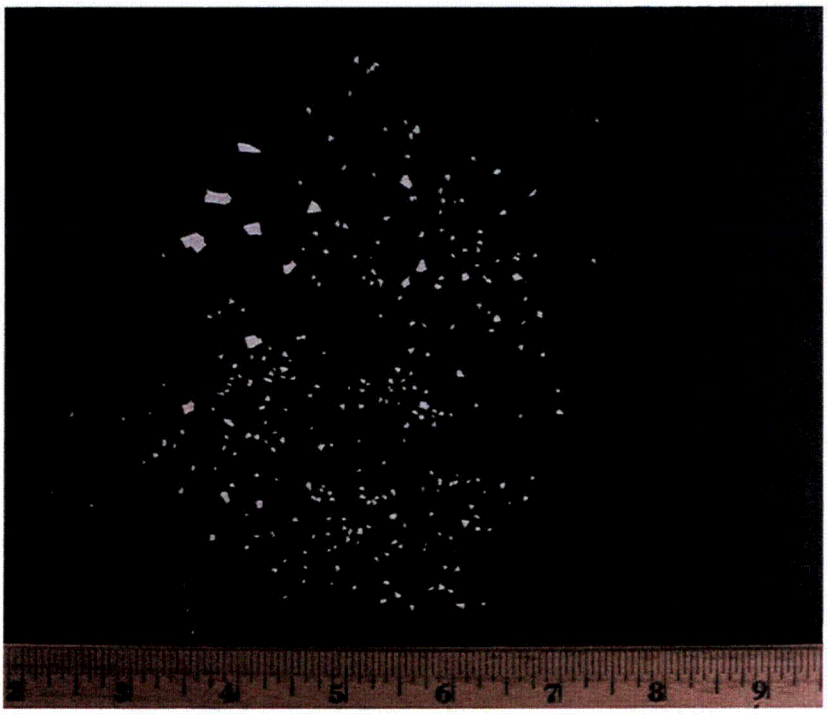


Figure O.1.3. Size Characterization Photo for ZE-Processed Debris. Total mass of particulate in photo was 0.12 g.

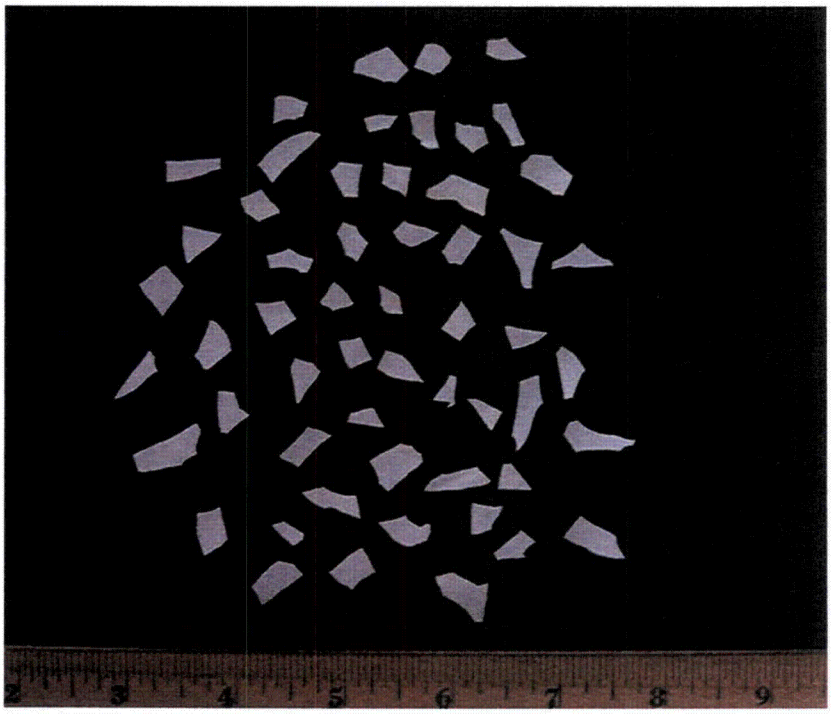


Figure O.1.4. Size Characterization Photo for ZE-Chips Debris. Total mass of particulate in photo was 1.0 g.

Table O.1.1. Particle Size Distribution for ALK-Processed Debris

Size Range		Major Axis		Minor Axis	
Lower Range (in.)	Upper Range (in.)	Particle Count[(a)]	Percentage by Number Count[(a)] in Size Range (%)	Particle Count[(a)]	Percentage by Number Count[(a)] in Size Range (%)
0.000	0.050	0	0	0	0
0.051	0.100	186	63	284	95
0.110	0.150	103	35	14	5
0.151	0.200	7	2	0	0
0.201	0.250	0	0	0	0
0.251	0.300	0	0	0	0
0.301	Infinite	0	0	0	0

(a) The sample had a total mass of 0.01 g and contained 298 particles

Table O.1.2. Particle Size Distribution for ALK-Chips Debris

Size Range		Major Axis		Minor Axis	
Lower Range (in.)	Upper Range (in.)	Particle Count[a]	Percentage by Number Count[a] in Size Range (%)	Particle Count[a]	Percentage by Number Count[a] in Size Range (%)
0.000	0.050	0	0	0	0
0.051	0.100	5	3	9	6
0.110	0.150	11	7	49	31
0.151	0.200	26	16	33	21
0.201	0.250	25	16	37	23
0.251	0.300	24	15	20	13
0.301	0.350	26	16	10	6
0.351	0.400	15	9	1	1
0.401	0.450	14	9	0	0
0.451	0.500	7	4	0	0
0.501	0.550	2	1	0	0
0.551	0.600	0	0	0	0
0.601	0.650	2	1	0	0
0.651	0.700	1	1	0	0
0.701	0.750	0	0	0	0
0.751	0.800	0	0	0	0
0.801	Infinite	1	1	0	0
(a) The sample had a total mass of 0.17 g and contained 159 particles					

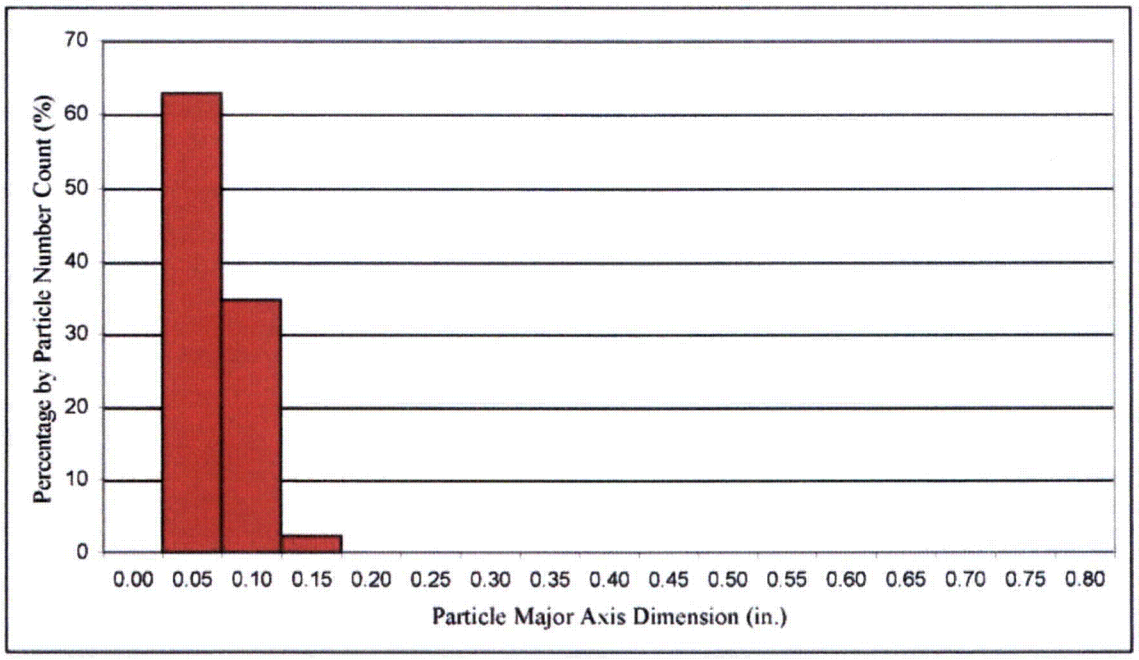
Table O.1.3. Particle Size Distribution for ZE-Processed Debris

Size Range		Major Axis		Minor Axis	
Lower Range (in.)	Upper Range (in.)	Particle Count[a]	Percentage by Number Count[a] in Size Range (%)	Particle Count[a]	Percentage by Number Count[a] in Size Range (%)
0.000	0.050	0	0	0	0
0.051	0.100	135	48	248	88
0.110	0.150	131	46	30	11
0.151	0.200	12	4	4	1
0.201	0.250	2	1	1	0
0.251	0.300	2	1	0	0
0.301	0.350	1	0	0	0
0.351	0.400	0	0	0	0
0.401	0.450	0	0	0	0
0.451	Infinite	0	0	0	0
(a) The sample had a total mass of 0.12 g and contained 283 particles					

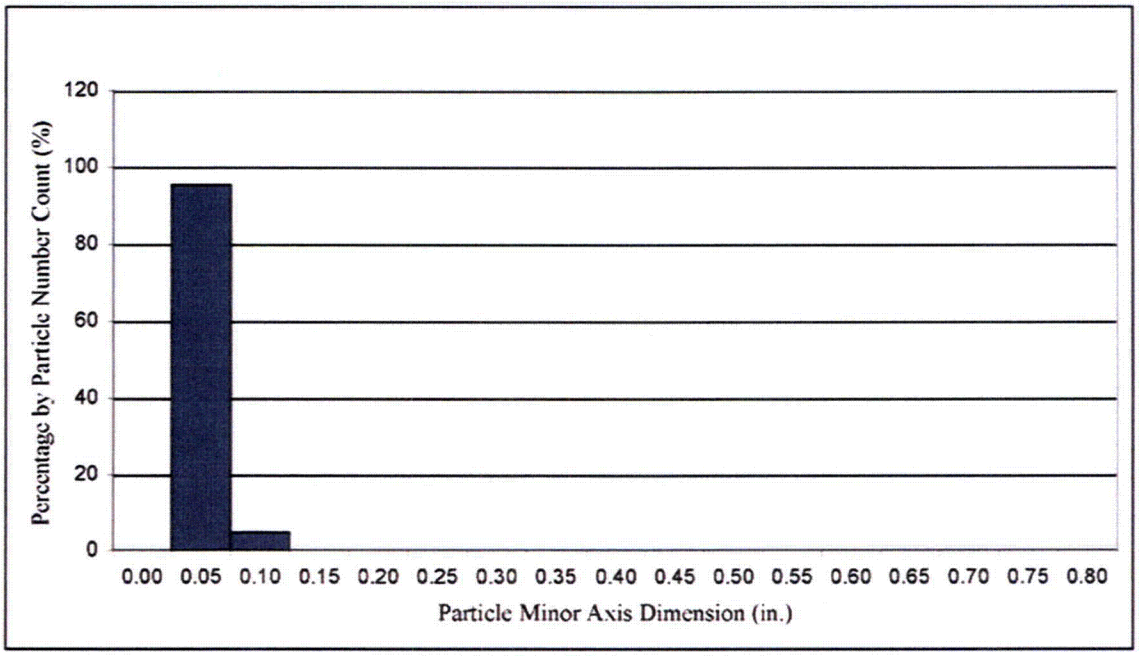
Table O.1.4. Particle Size Distribution for ZE-Chips Debris

Size Range		Major Axis		Minor Axis	
Lower Range (in.)	Upper Range (in.)	Particle Count[a]	Percentage by Number Count1 in Size Range (%)	Particle Count[a]	Percentage by Number Count1 in Size Range (%)
0.000	0.150	0	0	0	0
0.151	0.200	0	0	12	22
0.201	0.250	0	0	15	27
0.251	0.300	1	2	22	40
0.301	0.350	13	24	5	9
0.351	0.400	11	20	1	2
0.401	0.450	8	15	0	0
0.451	0.500	4	7	0	0
0.501	0.550	7	13	0	0
0.551	0.600	4	7	0	0
0.601	0.650	3	5	0	0
0.651	0.700	2	4	0	0
0.701	0.750	2	4	0	0
0.751	Infinite	0	0	0	0

(a) The sample had a total mass of 1.0 g and contained 55 particles.

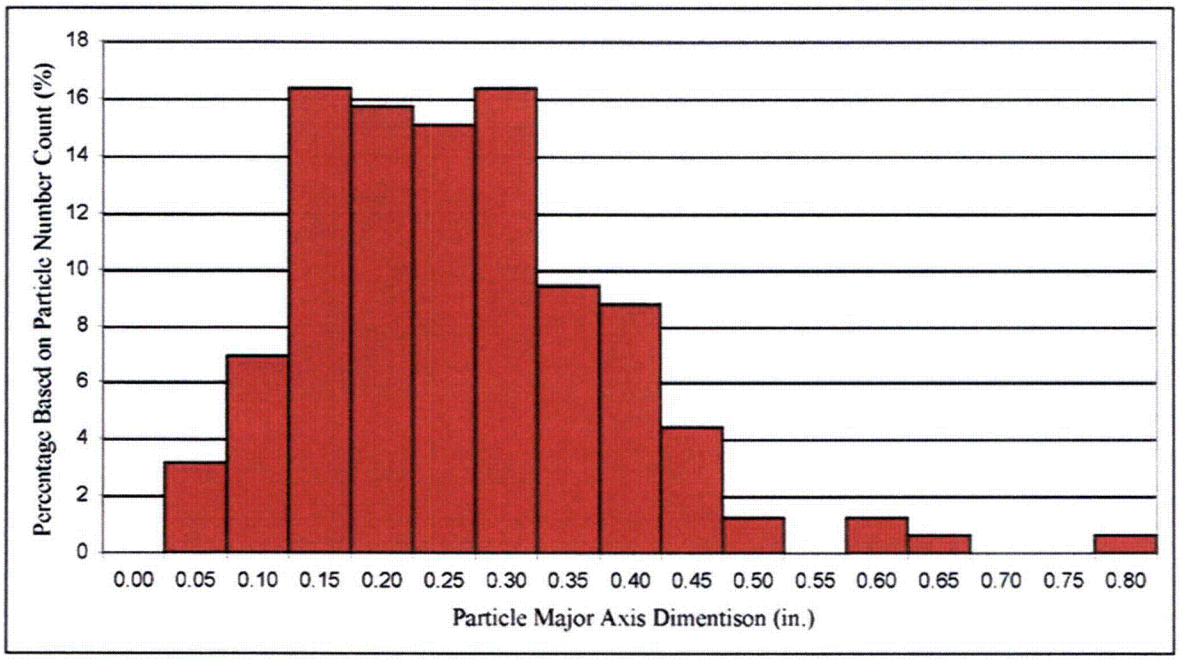


(a)

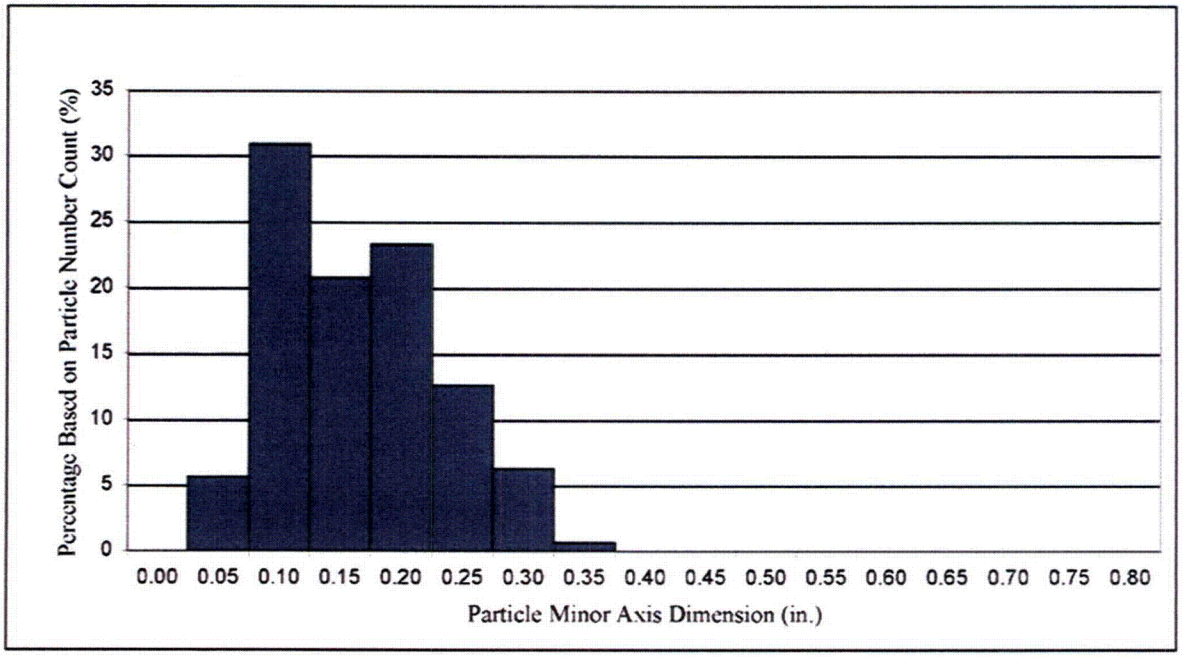


(b)

Figure O.1.5. Particle Size Histogram by Number Count for ALK-Processed Debris. Figures a and b are histograms for the major and minor axes, respectively. Distributions obtained from 0.01 g sample presented in Figure O.1.1 and Table O.1.1.

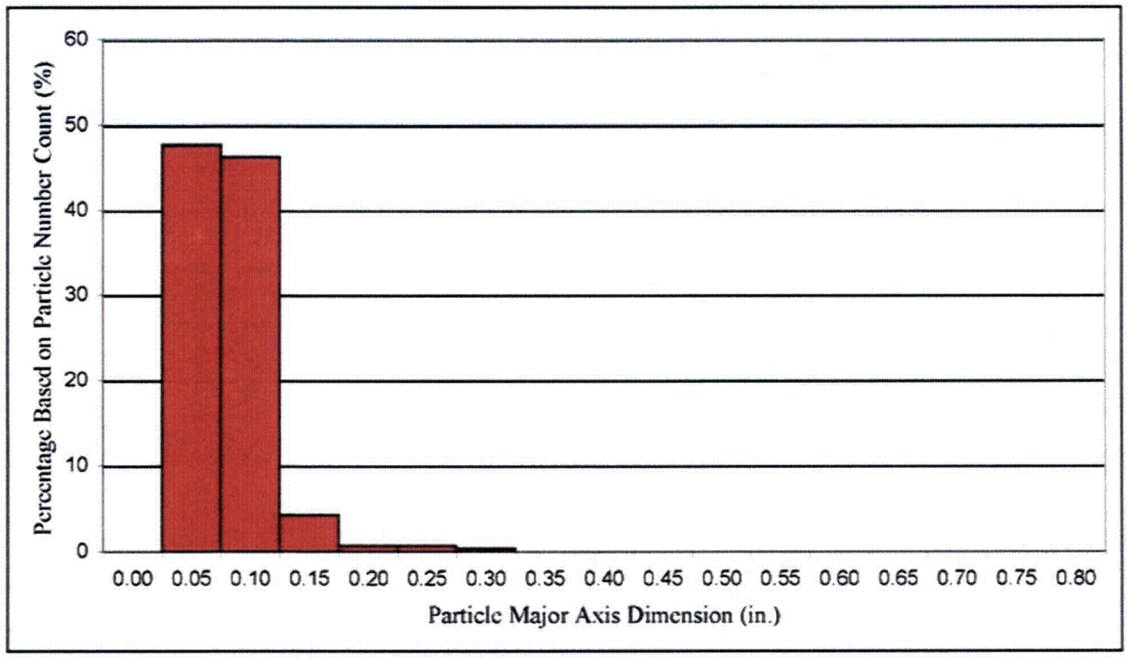


(a)

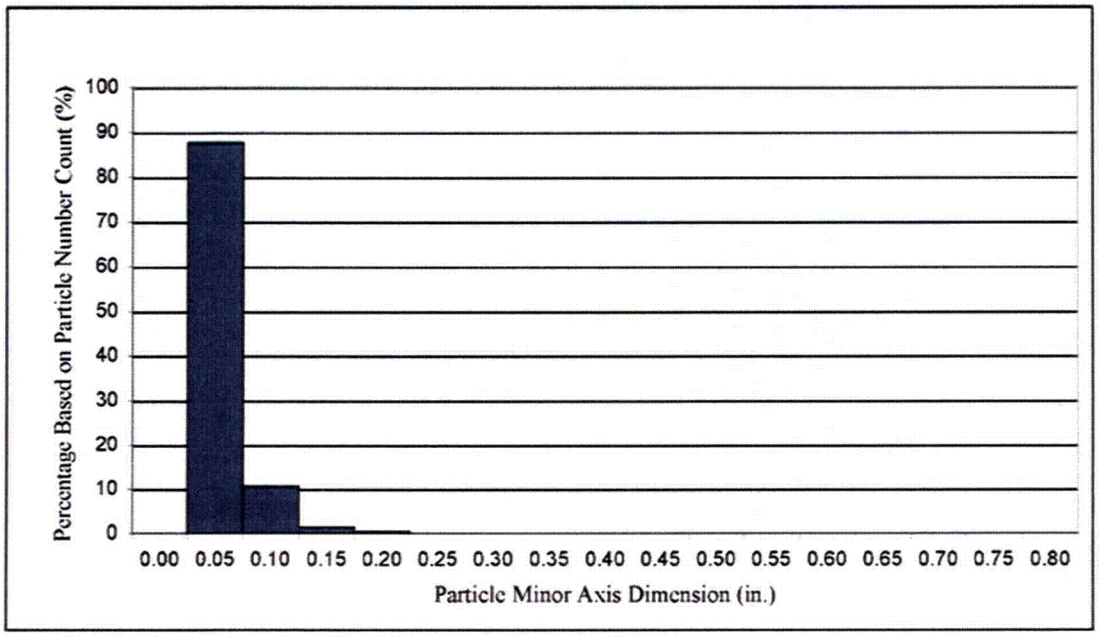


(b)

Figure O.1.6. Particle Size Histogram by Number Count for ALK-Chips Debris. Figures a and b are histograms for the major and minor axes, respectively. Distributions obtained from 0.17 g sample presented in Figure O.1.2 and Table O.1.2.

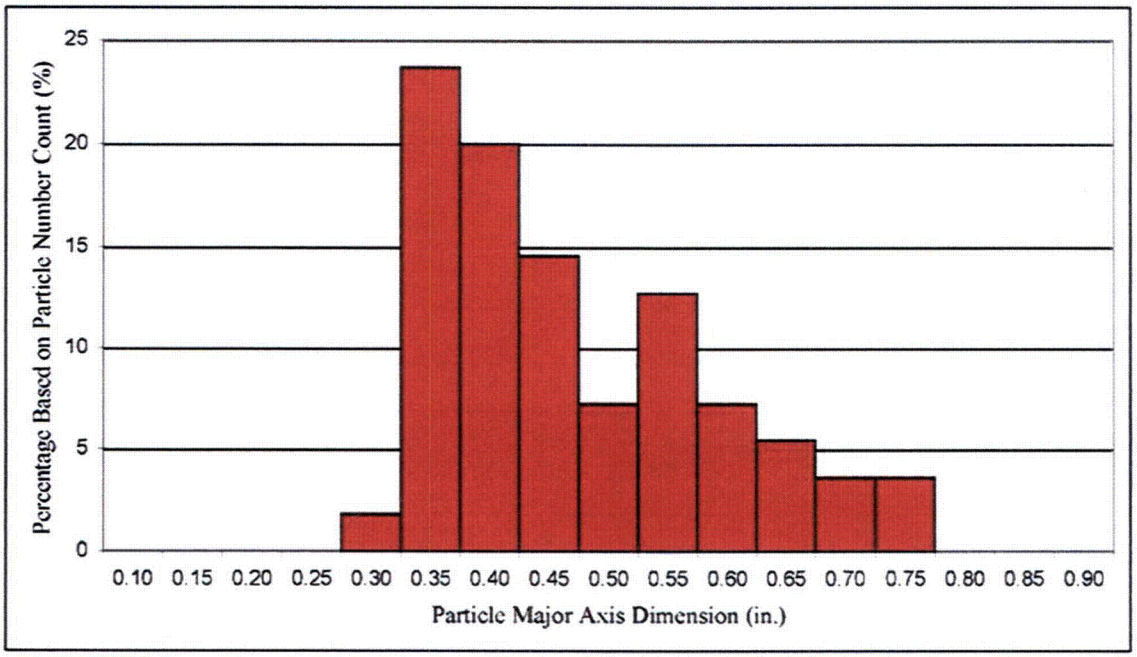


(a)

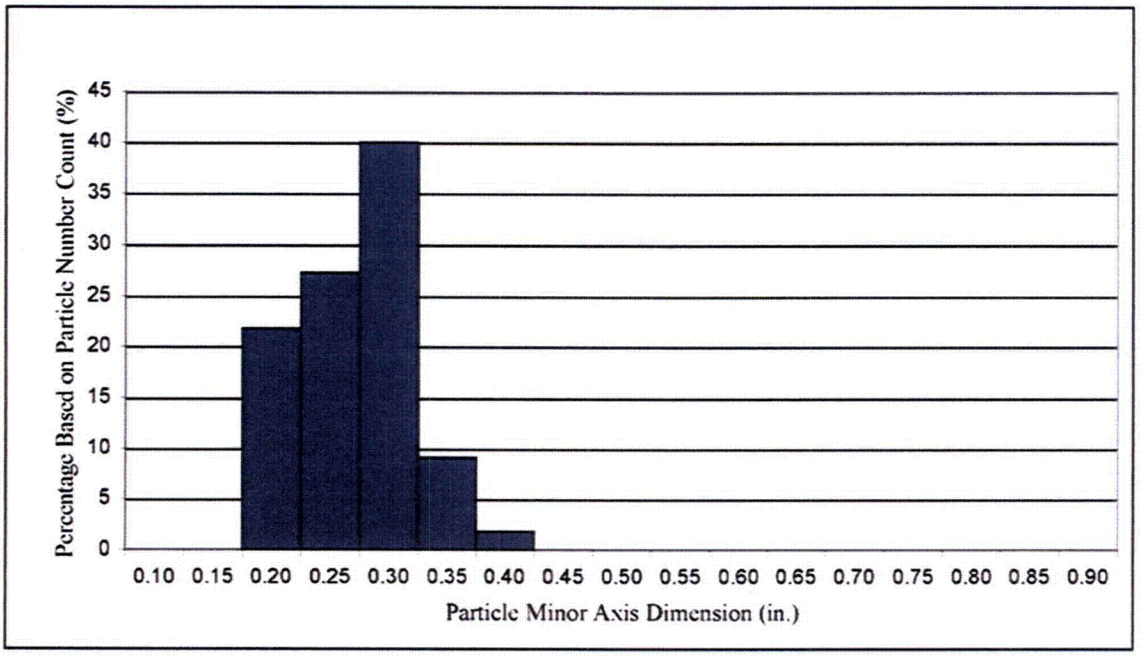


(b)

Figure O.1.7. Particle Size Histogram by Number Count for ZE-Processed Debris. Figures a and b are histograms for the major and minor axes, respectively. Distributions obtained from 0.12 g sample presented in Figure O.1.3 and Table O.1.3.



(a)



(b)

Figure O.1.8. Particle Size Histogram by Number Count for ZE-Chips Debris. Figures a and b are histograms for the major and minor axes, respectively. Distributions obtained from 1 g sample presented in Figure O.1.4 and Table O.1.4.

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10. SUPPLEMENTARY NOTES

William Krotiuk, NRC Project Manager

11. ABSTRACT *(200 words or less)*

The U.S. Nuclear Regulatory Commission (NRC) Generic Safety Issue-191 deals with the possibility that, during a loss of coolant accident in a pressurized water reactor, thermal insulation and other materials may be damaged and the debris transported to accumulate on the sump screens of the emergency core cooling system and containment sump. Over time, a debris bed could form, blocking the sump screen, increasing the pressure drop across the sump screen, and reducing the available suction head for the recirculation pumps resulting in the safety margins for pump operations being exceeded.

Pacific Northwest National Laboratory (PNNL) conducted experiments to help the NRC predict the flow through debris beds consisting of fiberglass and calcium silicate particulate. The effects of debris preparation on debris bed formation and pressure drop were evaluated and a metric developed for characterizing the preparation. Testing consisted of forming the debris bed within the test loop and obtaining a steady-state pressure drop at the bed formation velocity. The velocity was then changed incrementally through several cycles-increasing and decreasing-with a steady pressure measurement obtained at each flow set point. The loop temperature was then changed and the velocity variation sequence repeated.

The test setup, data acquisition system, procedures, experimental results, and observations are presented. In situ measurements and photographs show the debris beds contracting and relaxing with the cycling of flow velocity.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

PWR sump, sump screen, debris bed, porous medium, GSI-191, head loss, pressure drop, clogging, blockage

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