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Screen Penetration Test Report

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EXECUTIVE SUMMARY

This report describes a series of experiments that generated data needed to support the resolution of Generic Safety Issue 191. The experiments were performed under the direction of Los Alamos National Laboratory (LANL) in facilities operated by the Civil Engineering Department of the University of New Mexico.

This report addresses the propensity of different types of insulation debris (fibrous, particulate, and reflective-metallic-insulation) to penetrate pressurized-water-reactor sump screens with different size openings. The variables under consideration include the size of screen openings; the size, shape, and processing of different types of debris; the flow velocity across the screen; and how the debris reaches the screen (along the floor or in the flow). Results show that the fraction of debris that can penetrate the screens can be trivial or significant depending on all of these variables.

The experiments reported here are significant to the determination of the effect of the debris that passes through the screen on downstream components such as high-pressure safety injection system pumps and throttle valves. These effects are being investigated in ongoing research at the University of New Mexico as a subsequent step to the research reported here.

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ABBREVIATIONS

ECCS	Emergency Core Cooling System
GSI	Generic Safety Issue
LANL	Los Alamos National Laboratory
LOCA	Loss-of-Coolant Accident
NRC	Nuclear Regulatory Commission
PVC	Polyvinyl Chloride
PWR	Pressurized-Water Reactor
RMI	Reflective Metallic Insulation
US	United States

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1.0 INTRODUCTION

In the event of a loss-of-coolant accident (LOCA) within the containment of a pressurized-water reactor (PWR), piping thermal insulation and other materials in the vicinity of the break will be dislodged by break-jet impingement. A fraction of this dislodged insulation will be transported to the containment floor by the steam/water flows induced by the break and the containment sprays. Some of this debris eventually may be transported to and accumulated on the suction-sump-screens of the emergency-core-cooling-system (ECCS) pumps, or they may pass through the screens. Debris penetration could in some cases degrade ECCS performance to the point of failure.

The Generic Safety Issue (GSI)-191 study has addressed the issue of debris accumulation on the PWR sump screen and consequential loss of ECCS pump net positive suction head since 1999. Los Alamos National Laboratory (LANL) has been supporting the United States (US) Nuclear Regulatory Commission (NRC) in the resolution of GSI-191. Among the tasks already completed by LANL is experimental determination of transport, accumulation, and head loss across a PWR sump screen for flow conditions that are representative of those expected during ECCS recirculation and for debris types and quantities that may accumulate on the screen during a LOCA.

This document describes the first in a series of tests being conducted to address the effects downstream of the ECCS sump-screens. ECCS intake systems have been designed to screen out large post-LOCA debris materials. However, small-sized debris can penetrate these intake strainers or screens and reach critical pump components. Prior NRC-sponsored evaluations of possible debris and gas ingestion into ECCS pumps and attendant impacts on pump performance were performed in the early 1980s [1]. This issue is being revisited to factor in our improved knowledge of LOCA-generated debris.

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2.0 TEST FACILITY

The objective of this series of tests is to determine, through experiments, the types of insulation debris that would pass through the emergency-core-cooling-system sump screens. The primary test apparatus used to conduct the screen-penetration tests is a linear hydraulic flume. The flume consists of a sturdy open-top box 6.1 m (20 ft) long, 0.9 m (3 ft) wide, and 1.2 m (4 ft) high, with Plexiglas side panels for viewing the transport of debris (Figure 2-1). A schematic of the test facility is shown in Figure 2-2. This facility was designed and used previously as a test apparatus to simulate a variety of flow conditions to study debris-transport phenomena [2]. It was refurbished for the screen-penetration tests reported here. The flume rests on two 15-cm (6-in.) by 15-cm (6-in.) aluminum I-beams that, in turn, are supported on a wooden truss.

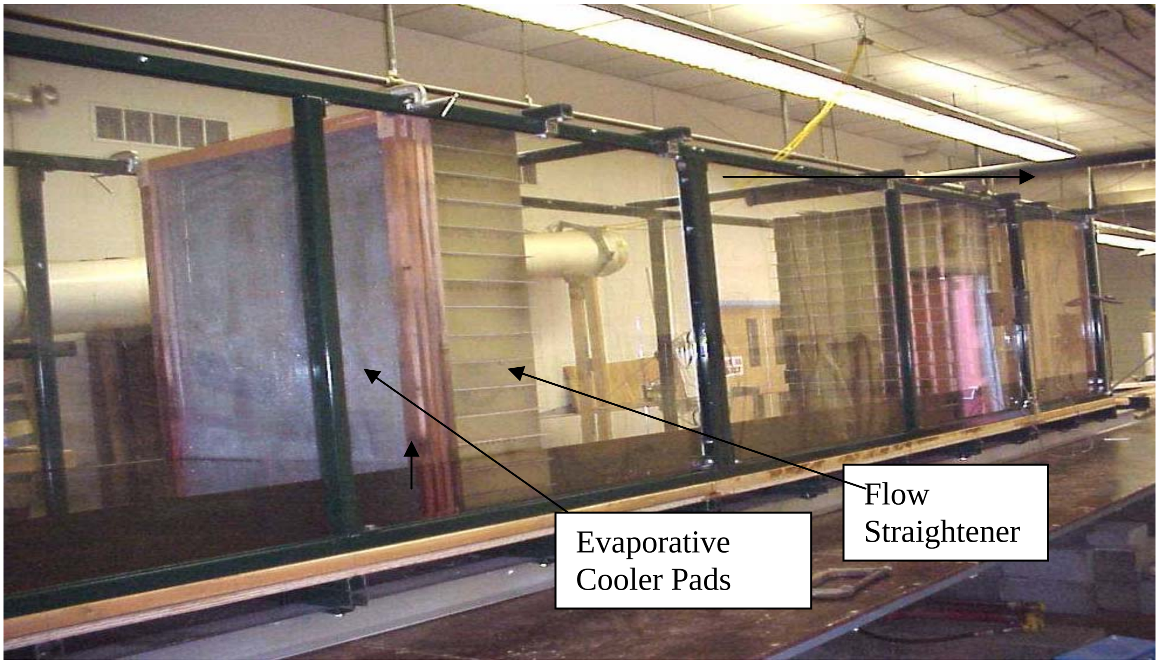

Figure 2-1 Linear Flume

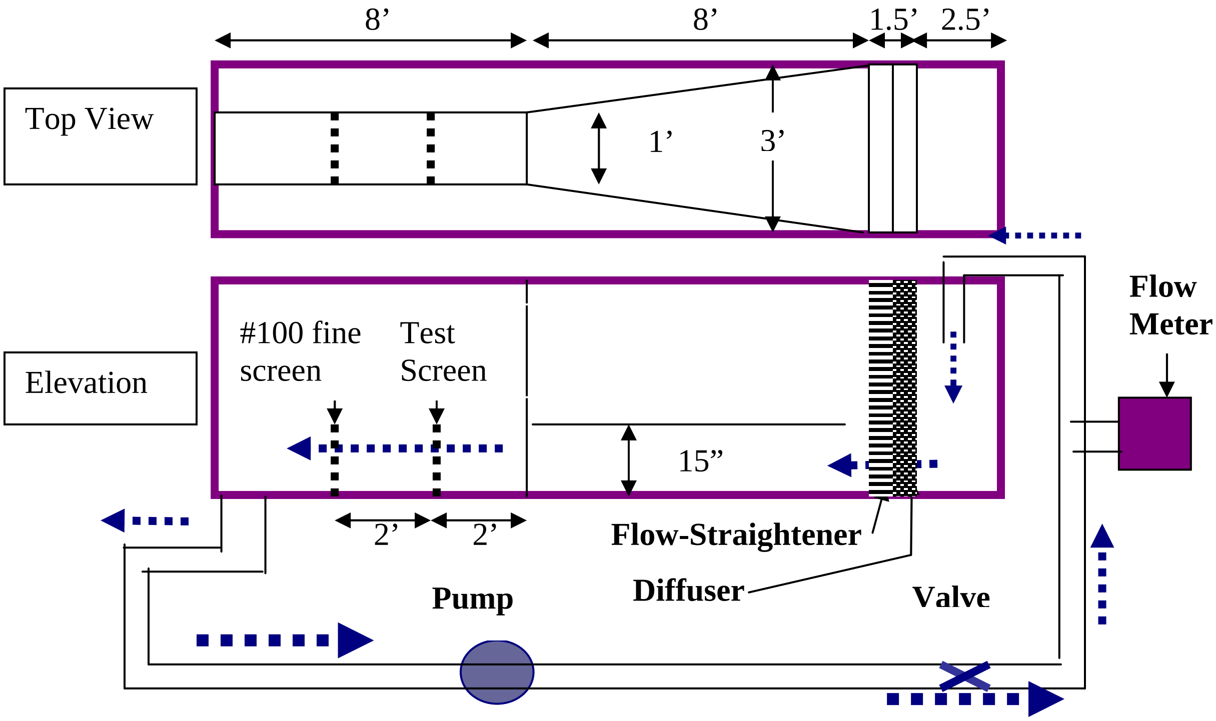

Figure 2-2 Schematic of Test Facility (Not to Scale)

The first 1.2 m (4 ft) of the flume is used for the water inlet and flow-conditioning apparatus. This apparatus consists of a set of evaporative cooler pads that minimize turbulence due to the flow injection and a set of aluminum sheets that straighten the flow (Figure 2-1). The floor of the flume is made of Plexiglas to obtain a surface roughness comparable to an epoxy-coated PWR floor. The walls and floor sections are supported structurally with uni-strut steel framework. A variable-speed centrifugal pump capable of 8.35 m^3/min (2200 gpm) is used to pump water from an underground reservoir through overhead piping to fill the test apparatus to the desired level. At the end of each test, water drains out through a 0.305-m (12-in.)-diameter outlet pipe at the opposite end of the flume.

To obtain maximum flow velocities at the sump screen, the flow cross section is reduced to force the flow to accelerate by converging the sidewalls. The channel width is linearly decreased from 0.91 m (3 ft) to 0.3 m (1 ft) at the downstream screen over a length of 2.4 m (8 ft). The plywood walls used for flow convergence are shown in Figure 2-3. Downstream from this device, 1.2-m (4-ft)-high Plexiglas walls confine the flow of water to the central 0.305-m (1-ft) width of the flume (Figure 2-4). Each Plexiglas wall is held in place by a 5-cm × 10-cm (2-in. × 4-in.) piece of wood at the bottom and by uni-strut metal supports at the top. Wooden supports [2.5 cm × 2.5 cm (1 in. × 1 in.)] are placed between the outer walls of the flume and these inner Plexiglas walls to prevent movement of the walls during the test caused by water pressure and handling of the test equipment. The bottom and side edges of the Plexiglas are caulked adequately to prevent water leakage during the tests.

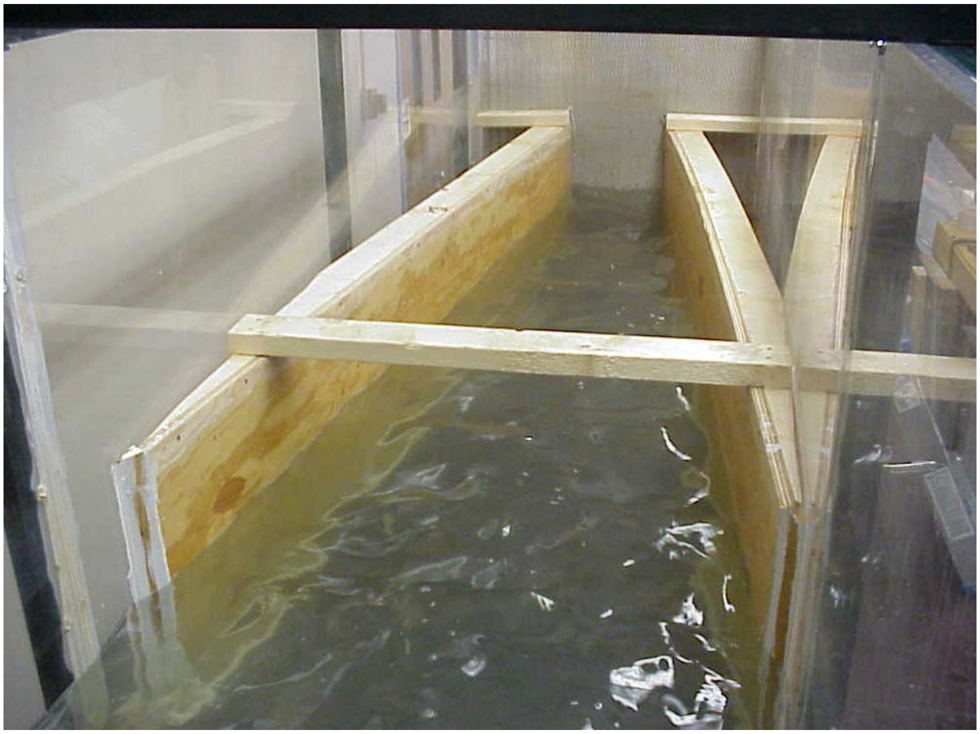

Figure 2-3 Converging Flow

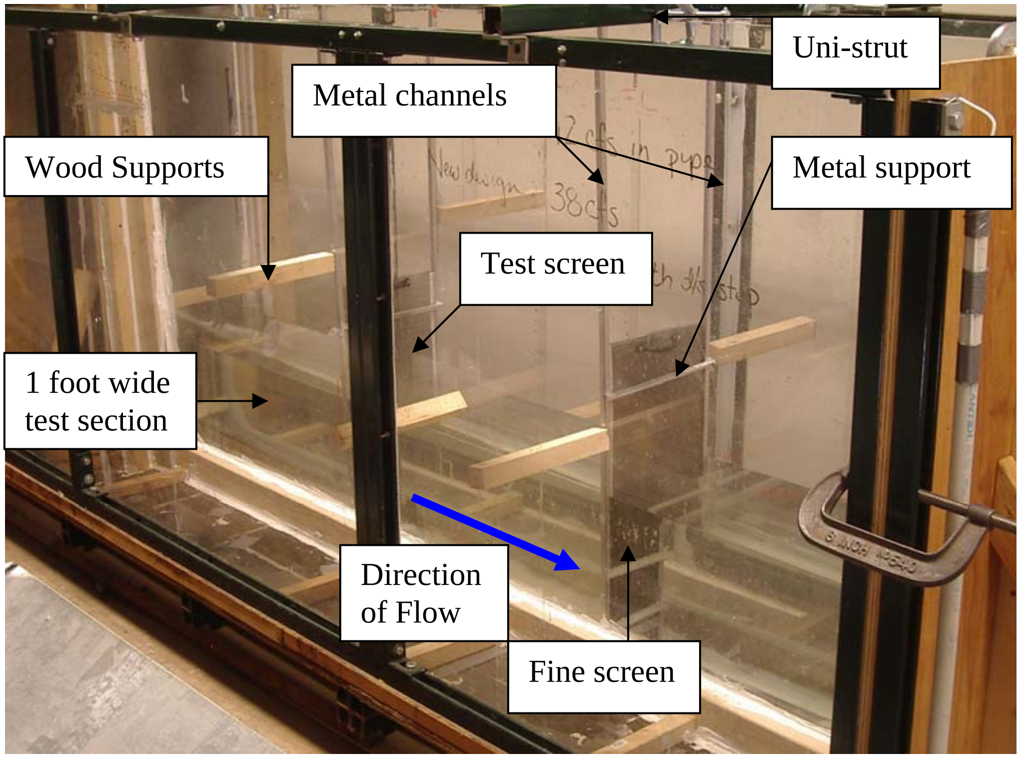

Figure 2-4 Test Section (1 ft Wide with Screens)

A pair of aluminum channels holds the test screen 0.61 m (2 ft) from the end of the converging section. The 1/4-in. and 1/8-in. screens with square openings can be removed and replaced to allow weighing of the material embedded on the screens and cleaning. Two horizontal pieces of aluminum channels provide additional support to these screens to prevent bowing due to the pressure of the flowing water. A fine (US-standard #100-sieve) screen is placed farther downstream to catch debris that passes through the screen. A coarse, stiff screen with 2.5-cm (1-in.), diamond-shaped openings is attached adhesively to this fine (#100 sieve) screen to provide structural rigidity. A 1.3-cm (1/2-in.)-high piece of sponge is attached to the bottom of the screens to allow them to seat evenly on the floor, thereby preventing any debris from escaping through the bottom.

3.0 SPECIMEN PREPARATION

Specimens of NUKON™, CalSil, and reflective metallic insulation (RMI) were used in the experiments. The preparation of NUKON™ and CalSil is identical to what has been reported in previous research [2], [3]. NUKON™ insulation debris is generated by using a leaf shredder to shred blanket insulation, followed by heating it to above 90°C to remove the coating on the surface of the glass fibers to more accurately simulate the post-LOCA condition of the fibers. The NUKON™ is then stirred for 5 min using a kitchen blender to separate the fibers and prevent clumping. CalSil was obtained as a mixture of clumps and fine powder form and does not need any additional preparation.

The stainless-steel RMI is prepared by cutting foils of the required sizes from a large 2.4-m × 1.2-m (8-ft × 4-ft) sheet of the material. For the 1/4-in. screen opening, two types of RMI debris are used: flat, square RMI sheets equal both to the size of the screen opening and to three-fourths of the screen opening. Thus, for the 1/4-in. screen opening, the sizes of the RMI debris used are 1/4 in. × 1/4 in. and 3/16 in. × 3/16 in. The third type of stainless-steel RMI is obtained by folding the 1/4-in.- and 1/8-in.-square pieces by hand to be used with the 1/4-in. and 1/8-in. screens, respectively, for tests conducted in June 2004.

The preparation of various insulation debris was based on experiments that previously were conducted on the generation of debris [4]. It was reported that some of the fibrous debris could be very small in size (microscopic). A small but not insignificant (4.3%) of the RMI was 1/4 in. in size. At a target distance of 5 to 11 times the break diameter, the amount of particulate (CalSil) generated by jet impingement could be as high as 46%. The fibrous insulation is coated with a thin layer of organic material, which causes it to float on water for long periods of time. However, this coating is lost after a short exposure to temperatures above 90°C, which is expected to occur in a typical post-LOCA environment. After this coating is lost, the fibrous insulation no longer floats on the surface.

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4.0 TEST PROCEDURE

Once the desired water depth is reached [(38 cm) (15 in.)] in the flume, a 5-hp recirculating pump is used to run the tests in a closed-loop configuration. The quantity of flow is adjusted using a control valve. With the valve completely open, the maximum flow rate is approximately 2.28 m^3/min (600 gpm). Based on the measured flow rate, the average flow velocities required for the execution of the tests are established. Water is allowed to recirculate for 5 min before debris is introduced into the flow. This recirculation allows the flow to reach a steady state and also allows any extraneous particles to be filtered out of the test section by the diffuser (evaporative cooler pads) at the upstream end of the flume. To ensure that extraneous material does not build up on the fine screen and influence the test results, the material is inserted after the water has recirculated for 5 min. Observations of the fine screen after this procedure indicated that this is sufficient to ensure that the fine screen is clean. However, for experiments involving the CalSil dust, these fine particulates pass through the evaporative cooler pads and could deposit on the fine screen.

Insulation debris then is introduced 0.61 m (2 ft) upstream from the screen through a 15.2-cm (6-in.)-diameter polyvinyl chloride (PVC) pipe. The bottom of this pipe rests on the floor of the flume; thus, the turbulence and the flow in the flume do not influence the debris as it settles inside the pipe. The presence of the pipe allows the debris to settle on the floor over a 2–3-min period before the PVC pipe is slowly lifted and the debris is subject to the flow conditions.

The flow rate is measured using a Hoffer (model HP-B series) flowmeter calibrated for the 15.2-cm (6-in.)-diameter recirculating pipe. The flowmeter also is calibrated at the beginning of the test program by measuring the flow velocities at the screen independently with a velocity probe. Each test is performed with approximately 10 g of debris of each type. This amount was selected to obtain a quantity sufficient to be weighed and yet not enough to cause any significant head loss on the screens. Two 0.305-m (12-in.)-wide flat trays with 1.3-cm (1/2-in.)-high metal edges are placed on the bottom of the test section immediately before the two screens. Each tray consists of a fine (#200-sieve) screen attached adhesively to a stiffer screen. These screens can be removed vertically with attached nylon strings to collect the debris on the floor. The fraction of debris that does not pass through the screens is determined by weighing the amount of debris caught on and before the test screen. The amount that passes through the screen is measured by carefully removing the material on the fine (#100-sieve) screen downstream and the material between the two screens. To weigh the amount of NUKON™, it must be separated from the water through a slow filtration process (Figure 4-1) before being dried in the oven. Small pieces of RMI that did not move to the trays must be removed by the technician getting into the flume at the end of the test (Figure 4-2) and collecting them by hand.

Figure 4-1 Filtration of NUKON™ To Remove Water

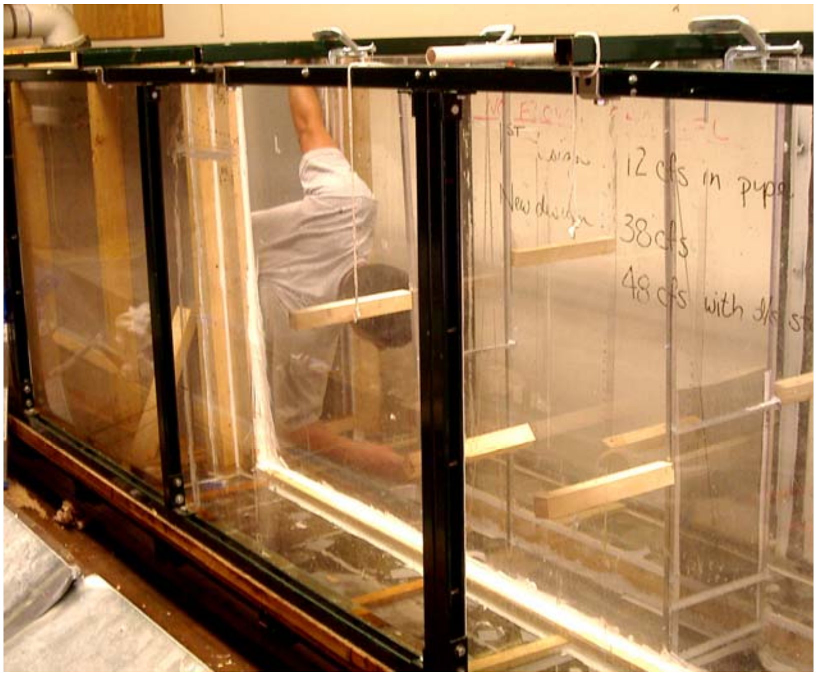

Figure 4-2 Removal of RMI by Hand inside the Flume

5.0 MAY 2004 TEST RESULTS

The test matrix shown in Table 5-1 was proposed in April 2004, based on the presumption that most of the NUKON™ and CalSil finer than a certain size will pass through the screens at velocities at and above 0.305 m/s (1 ft/s) and that the stainless-steel RMI will not transport at a velocity of 0.03 m/s (0.1 ft/s). The test matrix that was conducted in May 2004 is presented in Table 5-2. The results are tabulated in Appendix A. Additional tests were conducted in June 2004. The 0.1-ft/s flow velocity proposed in the original test matrix was not used for either the May or the June 2004 tests. Instead, the 0.2-ft/s flow velocity was chosen as the slowest flow velocity for the tests because the incipient floor transport velocity of some small NUKON™ pieces reported in NUREG/CR-6772 [2] was close to 0.1 ft/s. To ensure that the debris actually would reach the screen and not stay on the floor, the 0.2-ft/s flow velocity was chosen as the slowest velocity for all tests. The weights W_0, W_1, and W_2 in Appendix A represent the total amount of sample used, the amount retained before the test screen, and the amount retained before the fine screen used to capture the amount passing through, respectively.

Table 5-1 Originally Proposed Test Matrix

Flow Velocity ft/s	Screen Opening 1/4 in.			Screen Opening 1/8 in.			Screen Opening 1/16 in.		
	NUKON™	RMI[a]	CalSil	NUKON™	RMI[a]	CalSil	NUKON™	RMI[a]	CalSil
0.1	X		X	X		X	X		X
0.5	X	X	X	X	X	X	X	X	X
1.0	X	X	X	X	X	X		X	
2.0	X	X	X		X			X	

[a]Two sizes of flat square RMI and folded RMI per Section 2.0.

Table 5-2 Tests Completed in May 2004

Flow Velocity ft/s	Screen Opening 1/4 in.			Screen Opening 1/8 in.			Screen Opening 1/16 in.		
	NUKON™	RMI[a]	CalSil	NUKON™	RMI[a]	CalSil	NUKON™	RMI[a]	CalSil
0.2	X	X	X	X	X	X			
0.5	X	X	X	X	X	X			
1.0		X			X				

[a]Only two sizes of flat square RMI samples per Section 2.0.

It may be observed that the fraction of RMI that passes through the screen is very small but not zero. The amount passing through increases with increasing flow velocity because at low flow velocity, most of the RMI remains stagnant on the floor in a pile. With increasing flow velocity, more of the RMI gets to the screen, but most of it remains on the floor (Figure 5-1). Figure 5-2 shows some of the RMI trapped in the screen. The passage of RMI debris through screen openings of the same size (1/4-in.-size RMI for the screens with 1/4-in. openings) is indicative of the variation of the size and the physical influence of the water pressure and drag on the RMI pieces.

Figure 5-1 RMI at the Bottom of the Flume

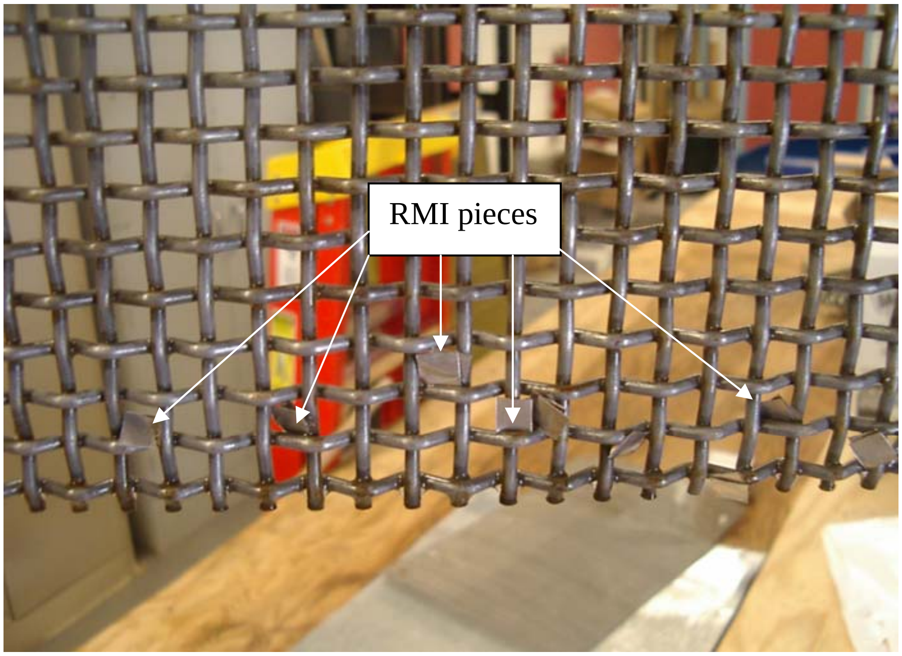

Figure 5-2 RMI Lodged in the 1/4-in. Screen Openings

Figure 5-3 shows NUKON™ remaining on the floor, and Figure 5-4 shows the finer-sized NUKON™ trapped on the fine screen downstream after passing through the test screen. Likewise, the larger clumps of CalSil remain on the floor (Figure 5-5) or stay on the test screen, whereas the finer particulates simply disperse in the water (making it murky) and partially collect on the fine screen downstream or on the tray on the floor (Figure 5-6). A large fraction of both NUKON™ and CalSil goes through the screens. As expected, the results show that, with the smaller screen opening, less of the NUKON™ and CalSil pass through. It also can be seen that all of the RMI introduced in the test section is accounted for ($W_0 = W_1 + W_2$). However, that is not the case for NUKON™ because it is difficult to collect all of the small fibrous pieces after the test, or for CalSil because a significant amount goes through the fine screen and is never recaptured.

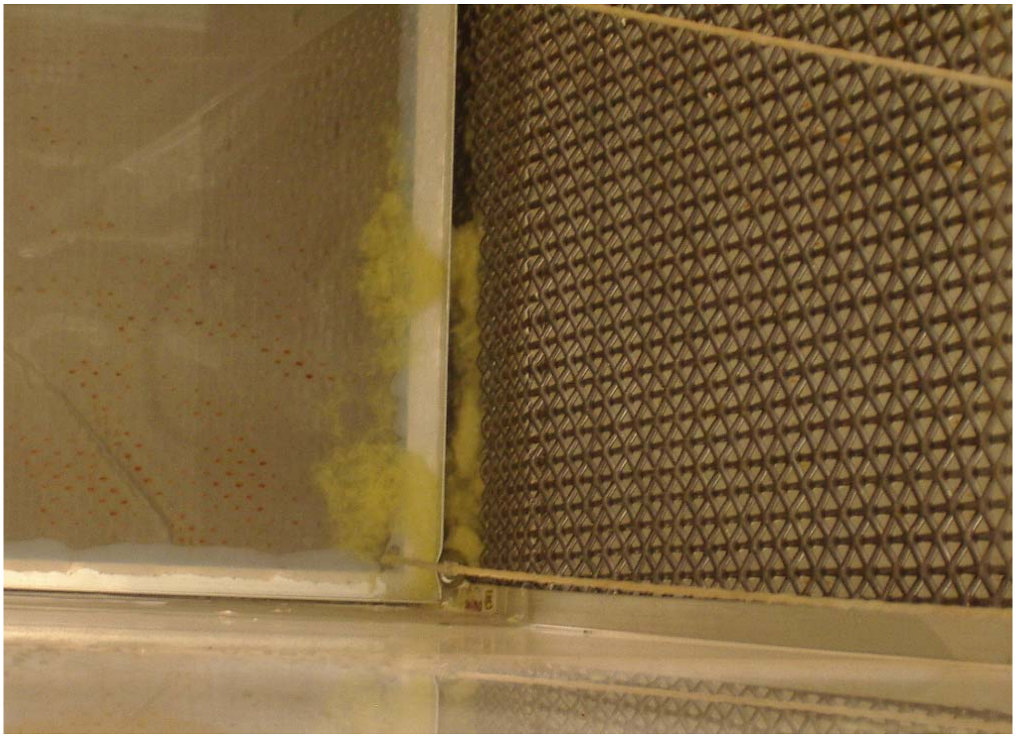

Figure 5-3 Larger Pieces of NUKON™ on the Floor

Figure 5-4 Finer-Sized NUKON™ Collected on the Fine Screen Located Downstream

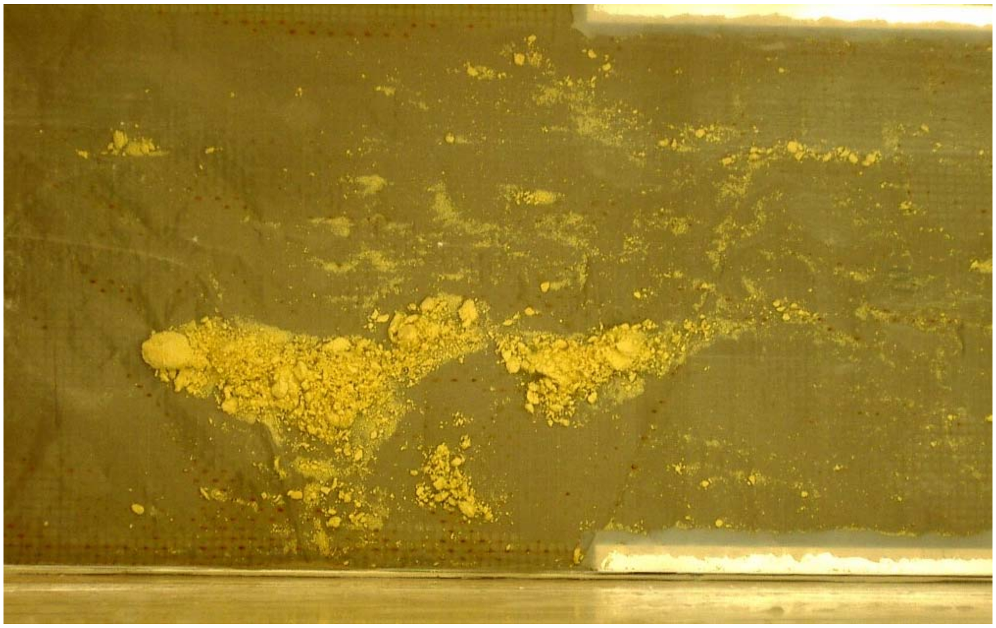

Figure 5-5 Larger Clumps of CalSil Remaining on the Floor

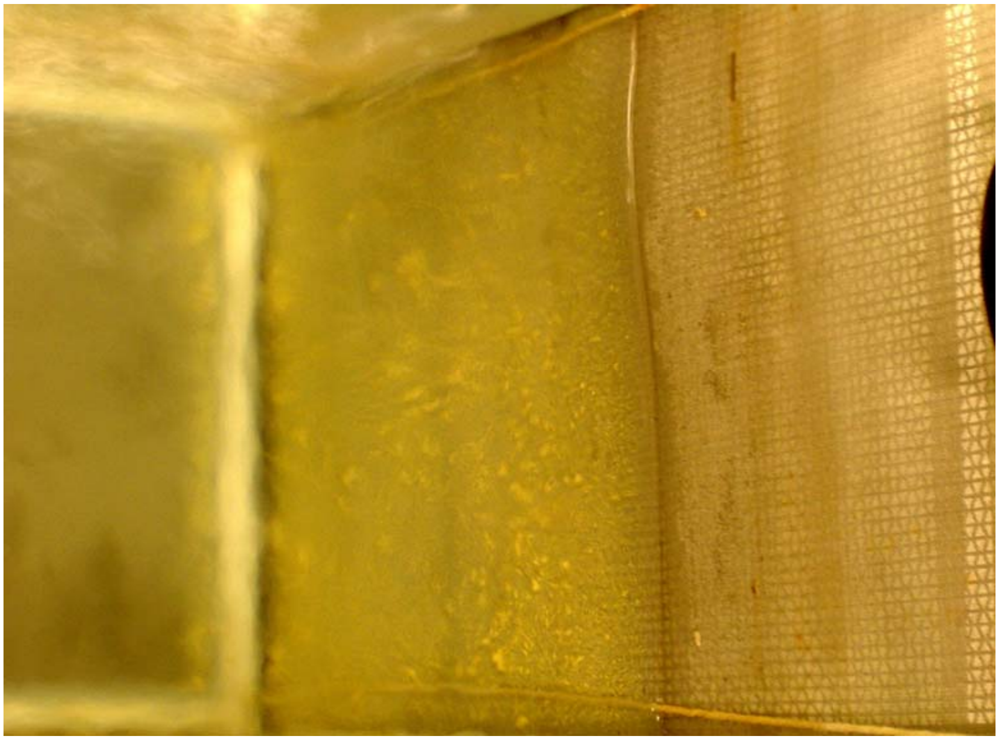

Figure 5-6 Smaller CalSil Captured by the Fine Screen and the Tray on the Floor

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6.0 RATIONALE FOR ADDITIONAL TESTS IN JUNE 2004

The difference between the originally proposed test matrix (Table 5-1) and the results reported here is based on the observations during the execution of the tests.

Testing RMI with 1/16-in. screen is not feasible because it is not possible to cut stainless-steel RMI into 1/16-in.-square pieces with reasonable accuracy. Testing at a screen velocity of 2.0 ft/s is not feasible without reducing the cross-section area of the test screen.

Stainless-steel RMI starts to move at a velocity of 0.2 ft/s; thus, tests are being conducted at this velocity, even though it was not part of the original tests matrix.

Substantial amounts of NUKON™ and CalSil transported even at a velocity of 0.1 ft/s, possibly due in part to the preparation of the NUKON™ by blending, which causes finer size distribution of this fibrous debris. This procedure was adopted to establish an upper bound of how much debris could pass through the screen. The size and weight fraction of debris generated by a LOCA was discussed in a previous report [5]. To study the effect of processing of the NUKON™, it was decided to conduct tests with the NUKON™ directly after processing in the leaf shredder without subjecting it to the subsequent blending process. These tests are identified in Table 6-1, which shows the remaining tests that were conducted in June 2004.

Table 6-1 Tests Completed in June 2004

Flow Velocity ft/s	Screen Opening 1/4 in.		Screen Opening 1/8 in.		Screen Opening 1/16 in.
	NUKON™[a]	RMI[b]	NUKON™[a]	RMI[c]	NUKON™[a]
0.2	X	X	X	X	X
0.5	X	X	X	X	X
1.0	X	X	X	X	X
2.0	X	X	X	X	

[a] NUKON™ from leaf shredder; not processed in blender.
[b] Two sizes of flat square RMI per Section 2.0 and one size of 1/2-in.- × 1/8-in.-size RMI.
[c] Only two sizes of flat square RMI samples per Section 2.0.

The RMI tests reported in Appendix A (corresponding to Table 5-2) were introduced on the floor. Because most of the RMI remained stationary on the floor and never reached the screen, only a small fraction of the RMI insulation passed through the screen. To separate the effect of floor transport from screen penetration in the test matrix shown in Table 6-1, the RMI was introduced into the flow at a distance of 15.2 cm (6 in.) from the test screen. The RMI first was submerged in water and introduced below the water surface of the flow to prevent it from floating on the surface (due to surface tension forces) before reaching the screen. Folded RMI pieces were not tested because of the perceived difficulty of folding small RMI pieces in a controlled manner to yield meaningful results.

A single set of RMI tests was conducted with an unusual aspect ratio of RMI. The RMI pieces were 1/2 in. × 1/8 in. in size and were used with a 1/4-in. test screen.

All of the results of the test matrix shown in Table 6-1 are provided in Appendix B.

Some of the material, especially finer debris introduced into the flow, is not captured by screen 1 or 2 and is not accounted for by the screen capture measurements ($W_0 \geq W_1 + W_2$). The destination of this lost material could be in any of three places:

1. before the test screen (drops to the floor or is never entrained),
2. between the two screens (passes through the sump screen but does not transport further), or
3. goes through the second screen and/or is too fine to capture.

Although it could be argued that material with destination 1 or 2 would not impact head loss or downstream components, it is appropriate to deal in terms of what is conservative for a given concern. The question becomes to which screen we attribute the lost material to in order to be conservative.

Two concerns have been identified for debris impact analyses: head loss across the sump screen and downstream component effects. Because the direction of conservatism differs for the two concerns, two different methods of reporting "% passing" through the sump screen must be considered. It should be noted that the ultimate destination of any material lost within the experiment does not invalidate the conservatisms imposed.

In the context of head loss, it is conservative to maximize what does not pass through the sump screen; thus, we would want to reflect minimally what is passed through screen 1. It is conservative if all of the lost material is treated as if it were retained on screen 1. The minimum quantity of material passing through the sump screen, "$\%passing_1$," is defined as $(W_2/W_0) \times 100$. In the context of adverse downstream effects, it is conservative to maximize what passes through the sump screen; thus, all of the lost material is treated as if it were retained on screen 2. The maximum quantity of material passing through the sump screen, "$\%passing_2$," is defined as $((W_0 - W_1)/W_0) \times 100$.

7.0 JUNE 2004 TEST RESULTS

Appendix B shows that the lack of blending had a major impact on the fraction of NUKON™ insulation that passed through any of the screens. Only a very small fraction of the NUKON™ went through the screens. The individual pieces of NUKON™ simply aggregated at the test screen (Figure 7-1).

Figure 7-1 NUKON™ That Is Tested Directly after Being Processed from a Leaf Shredder Forms Clusters at the Test Screen

Because all of the RMI now reached the screen, a significantly larger fraction went through. Especially for the RMI that was smaller than the screen opening, most of it penetrated the screen. RMI with the unusual aspect ratio of 1/2 in. × 1/8 in. demonstrated approximately the same fraction of penetration as the 1/4-in. × 1/4-in. RMI samples.

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8.0 CONCLUSIONS

It was observed that a significant amount of particulate CalSil insulation is expected to pass through a screen opening of any size. The only limiting factor with CalSil is the amount of particulates that forms large clumps and tends to remain on the floor rather than reaching the screen. Higher-flow velocity forces more of the CalSil to pass through the screen due to breakage of the clumps and a greater propensity of the CalSil to reach the screen.

With fibrous debris (NUKON™), the fraction passing through the test screen is very large if the NUKON™ is processed in a blender (into fine fibers) as opposed to being processed only in a leaf shredder. The fraction passing through each screen was less than 1% if the NUKON™ is only processed through a leaf-shredder. The fraction passing through the test screen is influenced to a much lesser extent by the velocity of flow at the screen. This observation has implications for the future tests that will be conducted on the downstream effects of the influence of fibrous debris on the throttle valve and the pump.

For the RMI, if the debris size is approximately the same as that of the screen opening, a very small fraction passes through. When the size of the RMI is somewhat smaller, more of it will tend to pass through. Once again, the fraction that passes through is influenced by the flow velocity, which tends to force more of the RMI through the screen. However, for debris that transports to the screen along the floor (as opposed to debris that is introduced into the flow near the screen), the fraction that penetrates the screen is small because of the propensity of the RMI to remain on the floor. RMI with the unusual aspect ratio of 1/2 in. × 1/8 in. demonstrated approximately the same fraction of penetration as the 1/4-in. × 1/4-in. RMI samples. These observations on the behavior of the RMI insulation are somewhat intuitive and confirm that no unexpected phenomena are likely to occur (such as water pressure bending the larger RMI pieces and forcing them through the screen or smaller RMI mostly getting caught in the screen wires as opposed to passing through).

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Appendix A. Test Results Corresponding to Table 5-2

SCREEN PENETRATION TEST RESULTS

Screen Size: 1/4 in. x 1/4 in.

Velocity (ft/s)	Type of Insulation Debris									
	NUKON™					CalSil				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.25	2.91	6.56	64.00	71.61	10.14	5.75	1.27	12.52	43.29
0.513	10.26	0.98	7.75	75.54	90.45	10.17	3.29	2.58	25.37	67.65

Velocity (ft/s)	Type of Insulation Debris									
	RMI 1/4 in. x 1/4 in.					RMI 3/16 in. x 3/16 in.				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.05	9.98	0.07	0.70	0.70	10.00	9.79	0.21	2.10	2.10
0.513	10.02	9.91	0.11	1.10	1.10	10.06	9.76	0.30	2.98	2.98
1.065	9.98	9.43	0.55	5.51	5.51	10.07	8.21	1.86	18.47	18.47

Screen Size: 1/8 in. x 1/8 in.

Velocity (ft/s)	Type of Insulation Debris									
	NUKON™					CalSil				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.07	2.06	6.37	63.26	79.54	10.01	6.45	0.42	4.20	35.56
0.513	10.36	2.49	6.61	63.80	75.97	10.26	3.77	1.93	18.81	63.26

Velocity (ft/s)	Type of Insulation Debris									
	RMI 1/8 in. x 1/8 in.					RMI 3/32 in. x 3/32 in.				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.07	10.05	0.02	0.20	0.20	10.05	9.96	0.09	0.90	0.90
0.513	10.04	9.95	0.09	0.90	0.90	10.02	9.69	0.33	3.29	3.29
1.065	10.08	8.55	1.53	15.18	15.18	10.07	7.87	2.20	21.85	21.85

W_0 = original amount of material
W_1 = amount of material retained on 1st screen
W_2 = amount of material retained on 2nd screen

%Passing$_1$ = $(W_2/W_o) \times 100$ (minimum, applicable for head-loss calculations)
%Passing$_2$ = $((W_o-W_1)/W_o) \times 100$ (maximum, applicable for downstream-component impact analyses)

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Appendix B. Test Results Corresponding to Table 6-1

SCREEN PENETRATION TEST RESULTS

Screen Size: 1/4 in. x 1/4 in.

Velocity (ft/s)	Type of Insulation Debris				
	NUKON™				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.18	9.91	0.09	0.88	2.65
0.513	10.18	9.88	0.06	0.59	2.95
1.065	10.18	9.66	0.00	0.00	5.11

Velocity (ft/s)	Type of Insulation Debris									
	RMI 1/4 in. x 1/4 in.					RMI 3/16 in. x 3/16 in.				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.05	9.21	0.84	8.36	8.36	10.04	2.62	7.42	73.90	73.90
0.513	10.05	8.68	1.37	13.63	13.63	10.04	2.45	7.59	75.60	75.60
1.065	10.05	8.33	1.72	17.11	17.11	10.04	3.69	6.35	63.25	63.25

Screen Size: 1/8 in. x 1/8 in.

Velocity (ft/s)	Type of Insulation Debris				
	NUKON™				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.17	9.85	0.06	0.59	3.15
0.513	10.17	9.76	0.08	0.79	4.03
1.065	10.17	9.72	0.00	0.00	4.42

Velocity (ft/s)	Type of Insulation Debris									
	RMI 1/8 in. x 1/8 in.					RMI 3/32 in. x 3/32 in.				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.04	9.03	1.01	10.06	10.06	10.00	2.60	7.40	74.00	74.00
0.513	10.04	8.55	1.49	14.84	14.84	10.00	2.34	7.66	76.60	76.60
1.065	10.04	7.77	2.27	22.61	22.61	10.00	4.03	5.97	59.70	59.70

Screen Size: 1/16 in. x 1/16 in.

Velocity (ft/s)	Type of Insulation Debris				
	NUKON™				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.21	9.81	0.09	0.88	3.92
0.513	10.21	9.77	0.11	1.08	4.31
1.065	10.21	9.69	0.00	0.00	5.09

Screen Size: 1/4 in. x 1/4 in.

Velocity (ft/s)	Type of Insulation Debris				
	RMI 1/2 in. x 1/8 in.				
	W_o (g)	W_1 (g)	W_2 (g)	%Passing$_1$	%Passing$_2$
0.208	10.01	8.57	1.44	14.39	14.39
0.513	10.01	8.52	1.49	14.89	14.89
1.065	10.01	8.87	1.14	11.39	11.39

W_0 = original amount of material
W_1 = amount of material retained on 1st screen
W_2 = amount of material retained on 2nd screen

%Passing$_1$ = (W_2/W_o) × 100 (minimum, applicable for head-loss calculations)
%Passing$_2$ = ((W_o-W_1)/W_o) × 100 (maximum, applicable for downstream-component impact analyses)