Performance Contracting, Inc. ECCS Sure-Flow™ Strainer Data Report

Revision 0

WO4536-01

December 1996

Prepared by
Continuum Dynamics, Inc.
P.O. Box 3073
Princeton, New Jersey 08543

Project Manager

Andrew E. Kaufman

Authors
Andrew E. Kaufman
Robert W. Diertl
Richard G. Louderback

Prepared for
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

EPRI Project Manager
Leonard Loflin
Plant Support Engineering

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

ORGANIZATION(S) THAT PREPARED THIS REPORT

Continuum Dynamics, Inc.

ORDERING INFORMATION

Requests for copies of this report should be directed to the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, CA 94523, (510) 934-4212. There is no charge for reports requested by EPRI member utilities.

ABSTRACT

A Performance Contracting, Inc. (PCI) Sure-Flow™ strainer was tested under a variety of debris and flow conditions in the Boiling Water Reactor Owners' Group (BWROG) test facility at the EPRI facility in Charlotte, North Carolina. The strainer was tested with fibrous insulation, simulated corrosion products, and reflective metal insulation (RMI). This report documents the head loss results from the five tests conducted in October 1996.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1

INTRODUCTION

In the event of a Loss of Coolant Accident (LOCA) in a Boiling Water Reactor (BWR) nuclear power plant, insulation installed on piping can reach the wetwell which supplies water to the Emergency Core Cooling System (ECCS). This insulation combined with corrosion products and other debris can migrate and block strainers installed on suction lines supplying the ECCS pumps. Relatively small amounts of glass fiber insulation combined with corrosion products have been shown to result in significant pressure drop across a strainer screen. An alternate suction strainer design, the Sure-Flow™ strainer, was provided by PCI to evaluate its performance under different flow and debris loads. From 28 through 30 October 1996, Continuum Dynamics, Inc. conducted a series of tests on this strainer. Tests were conducted at the Electric Power Research Institute Non Destructive Evaluation Center in Charlotte, North Carolina.

Testing was conducted following the Plan for Testing PCI Strainer, Revision 1, 28 October 1996 (Ref. 1). Test procedures and materials essentially duplicated BWROG procedures and materials for strainer testing.

2

TEST FACILITY

A schematic of the test facility is shown in Figure 2-1. The strainer was mounted horizontally to a 24 inch tee in a nominally 50,000 gallon vessel. Typically, the vessel was filled with 40,000 gallons of water. Two centrifugal pumps capable of producing 10,000 GPM were used to provide system flow controlled by valves on the pump outlets. The flow returned to the vessel through a venturi and then through a pipe whose exit was centered in the vessel and directed down toward the floor. This pipe orientation prevented material from settling on the vessel floor.

The piping configuration also allowed the strainer to be backflushed. Backflush flowrates up to 5000 GPM can be obtained, but backflush duration is often limited because debris from the vessel can be pulled inside the strainer because of the location of the backflush inlet pipe (see Figure 2-1).

Instrumentation

A schematic illustrating the instrument locations is shown in Figure 2-2. The head loss across the strainer and debris bed is measured by a Rosemount 1151 smart differential pressure transmitter that is connected to the blind flange of the strainer tee. The flow rate is measured by the venturi in the return leg of the piping and another a Rosemount 1151 smart differential pressure transmitter. The outputs of these transmitters were connected through Sensotec GMA displays and amplifiers (0.2% accuracy) to a computer controlled DATAQ DI-220 12 bit data acquisition system. Fiber, simulated corrosion products and RMI were weighed on an Ohaus model DS10L scale and water temperature was measured with a thermometer. Table 2-1 lists the instruments used in the test program.

Table 2-1
Instrument List

Symbol	Instrument	Range	Accuracy	Comment
DP1	Differential Pressure Transmitter	0-650 inches of water	+/- 1 inch of water	Strainer head loss.
DP3	Differential Pressure Transmitter	0-250 inches of water	+/- 0.4 inches of water	Used with venturi (+/- 300 GPM accuracy).
A/D	Data Acquisition	0-5 volts	+/- .025%	Record pressure and flow data.
T1	Thermometer	35-120 degrees F	+/- 3 degrees F	Water temperature commercial grade.
B1	Balance	0-100 pounds	+/- 0.5 pounds	Weigh debris commercial grade.

Strainer

A photograph of the PCI Sure-Flow™ strainer is shown in Figure 2-3. A sketch of the strainer showing some important dimensions is shown in Figure 2-4.

Debris Materials

NUKON® Base Wool Insulation was used as the fibrous insulation for this test program. The insulation was supplied, prepared and weighed by PCI and supplied in 25 pound bags. Samples of the insulation were collected to provide an estimate of the size distribution. An analysis of the shredded fibers showed a similar size distribution as was used in the BWROG tests.

Black Iron Oxides obtained from Hansen Engineering, Inc. were used to simulate corrosion products with a distribution of 95% Grade 2008 and 5% Grade 9101-N-40 by weight .

Reflective Metal Insulation (RMI) was also used during testing. Stainless steel foils with a thickness of 2.5 mils were supplied by Darchem Engineering, Ltd. The foils were cut into nominally 3/8, 3/4, 1.5, 3, and 6 inch squares and then crumpled to simulate RMI debris. The material was purchased and processed by EPRI. Based on EPRI documentation, the two smallest size categories were crumpled by the garden/leaf shredder and the remaining sizes were crumpled by hand. The resulting RMI debris was similar to the RMI used in the BWROG tests.

Summary of Test Procedures

The test procedures duplicated the test procedures used in the BWROG strainer tests. The procedures are summarized below.

The main test procedure defines the steps necessary to perform one complete test for measuring strainer head loss. The main steps in this procedure include system start up, material addition, data acquisition, flow rate control , backflushing and test termination. Data acquisition is started before the pumps are turned on and material is added to the vessel after the flow rate has been established. The time of material introduction is recorded. The amount of material added is determined by the test matrix. Simulated corrosion products are always added first and allowed to mix in the vessel before the other debris is added. Simulated corrosion products are added dry, while shredded fiber is soaked first to ensure it will sink.

During a test the flow rate is maintained at a nearly constant value determined by the test matrix, unless the strainer maximum pressure drop is reached or the maximum pump flow is achieved. After the strainer head loss has reached approximately steady state, the flow rate can be adjusted down and up (a flow sweep) to obtain head loss at different flow rates, and if required, the strainer can be backflushed. The strainer is backflushed by shutting off the pumps and reconfiguring the valves so that pump #2 can pull water from the backflush line into the strainer. Pump #2 is turned on and then the backflush valve is opened until the backflush gauge reads the pressure corresponding to the desired flowrate. The flow is then maintained at this flowrate for the desired time. A run is terminated when the strainer head loss reaches approximately steady state or a determined value of head loss has been achieved (after conducting any required flow sweeps or backflush). After test termination, a backup copy of the digitally recorded data is made and the ending water temperature is taken.

Daily procedures are followed to check the differential pressure transducers and data acquisition system. Differential pressure cell zeros and known water height readings are taken and compared to the transducer output. The output of the data acquisition system is also checked to insure it is operating correctly and that the instruments are correctly connected. Periodic confidence checks on the scales and thermometer are also conducted as required.

Also associated with each main test procedure is a material preparation procedure which defines how much material is to be added to the vessel. This procedure defines the methods to identify and quantify the fibrous insulation, simulated corrosion products and other debris to be used for each test. Samples of fibrous insulation prepared by PCI were taken to characterize its size distribution. RMI was provided by EPRI in boxes marked with the square feet of area and was not weighed. All material used in the program is identified by a unique number.

Data is stored on disk as voltages from the differential pressure transducers. Using the calibration curves for each instrument, the voltages are converted to engineering units (either inches of water or gallons per minute). The clean head loss as a function of flow rate is subtracted from each head loss data point to obtain the head loss across the debris bed. The data is plotted in Appendix A as a function of time and approximate steady state values are tabulated in Section 4.

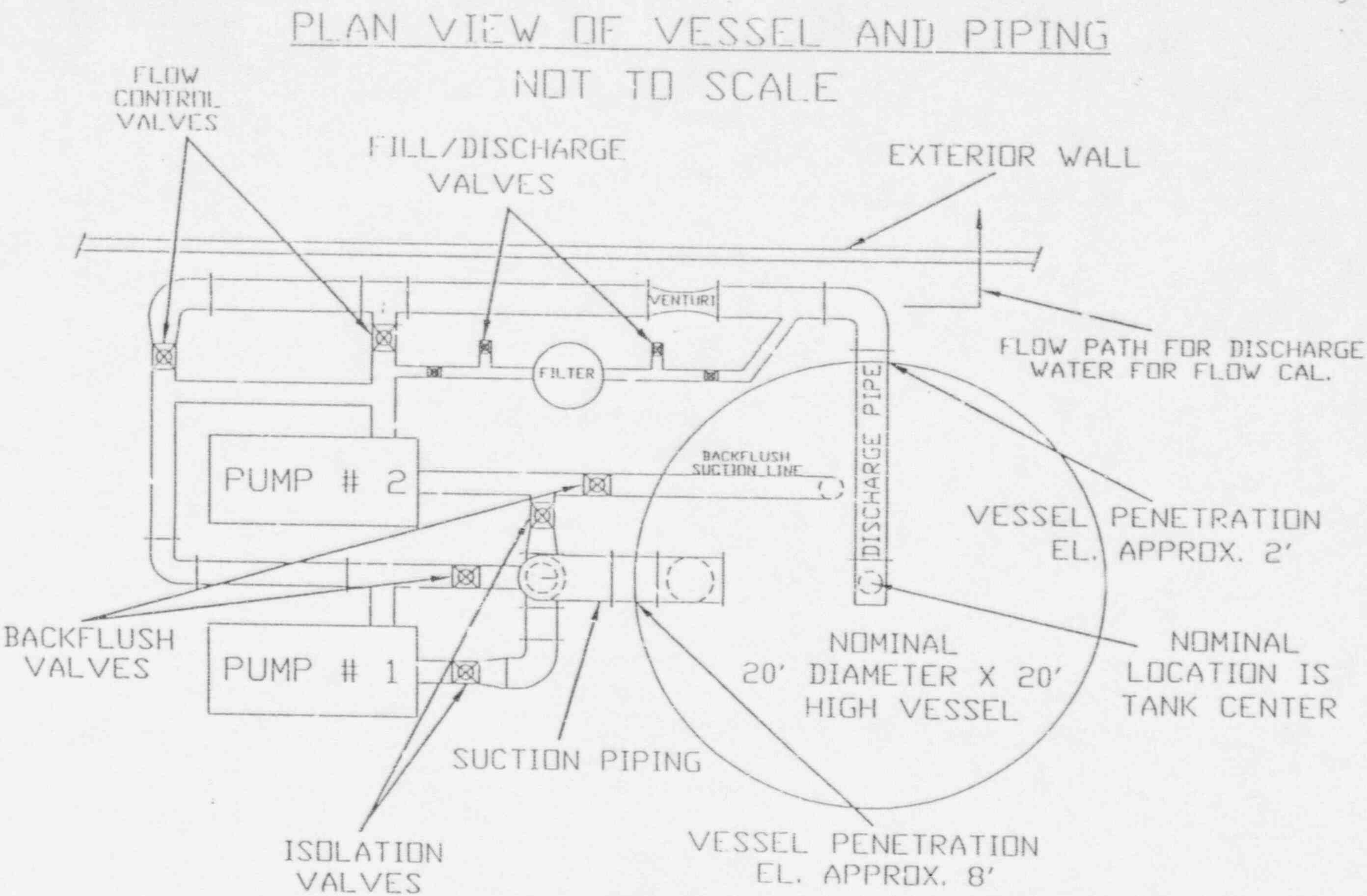

Figure 2-1 Schematic of test facility.

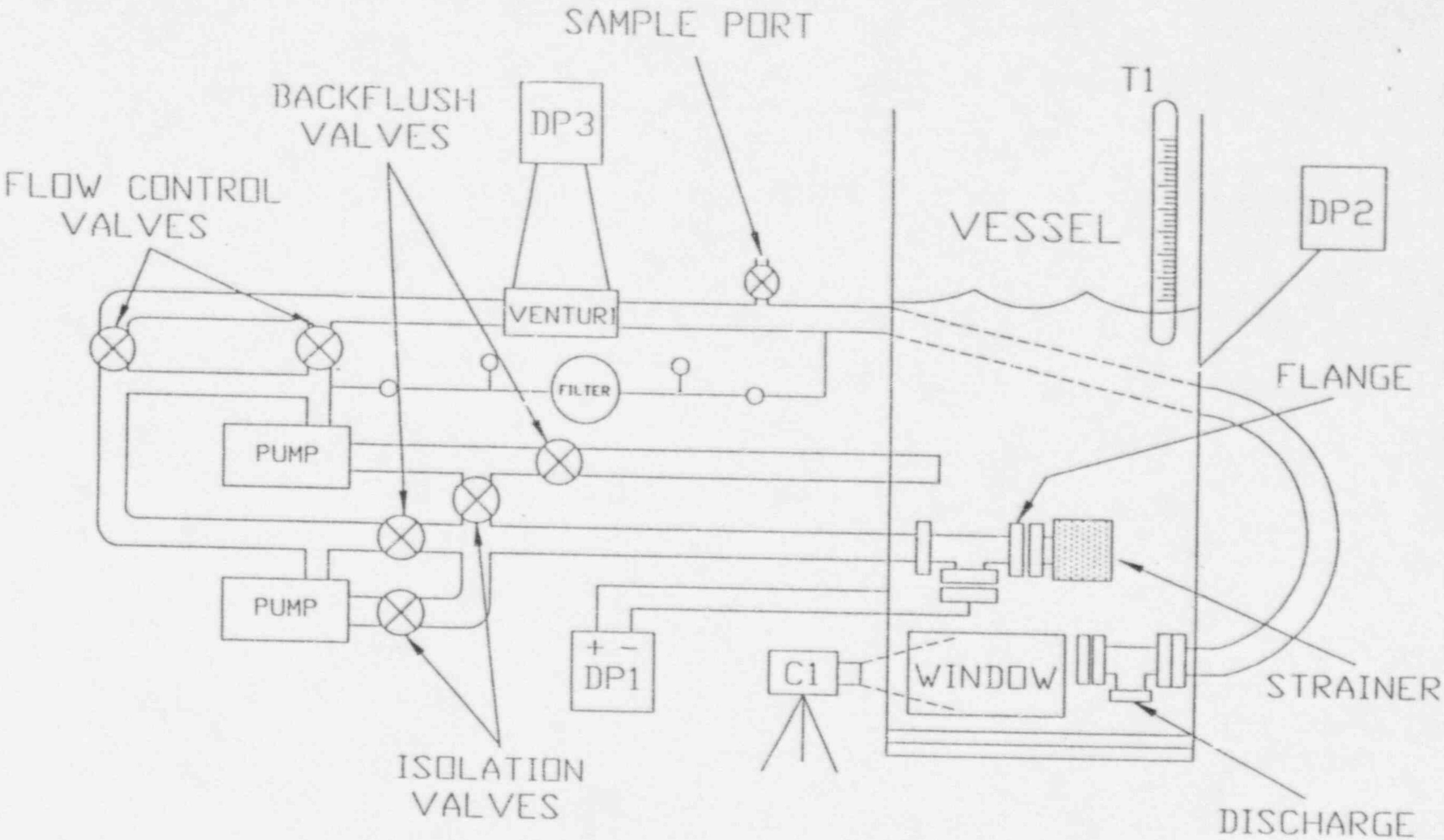

Figure 2-2 Schematic of instrument locations.

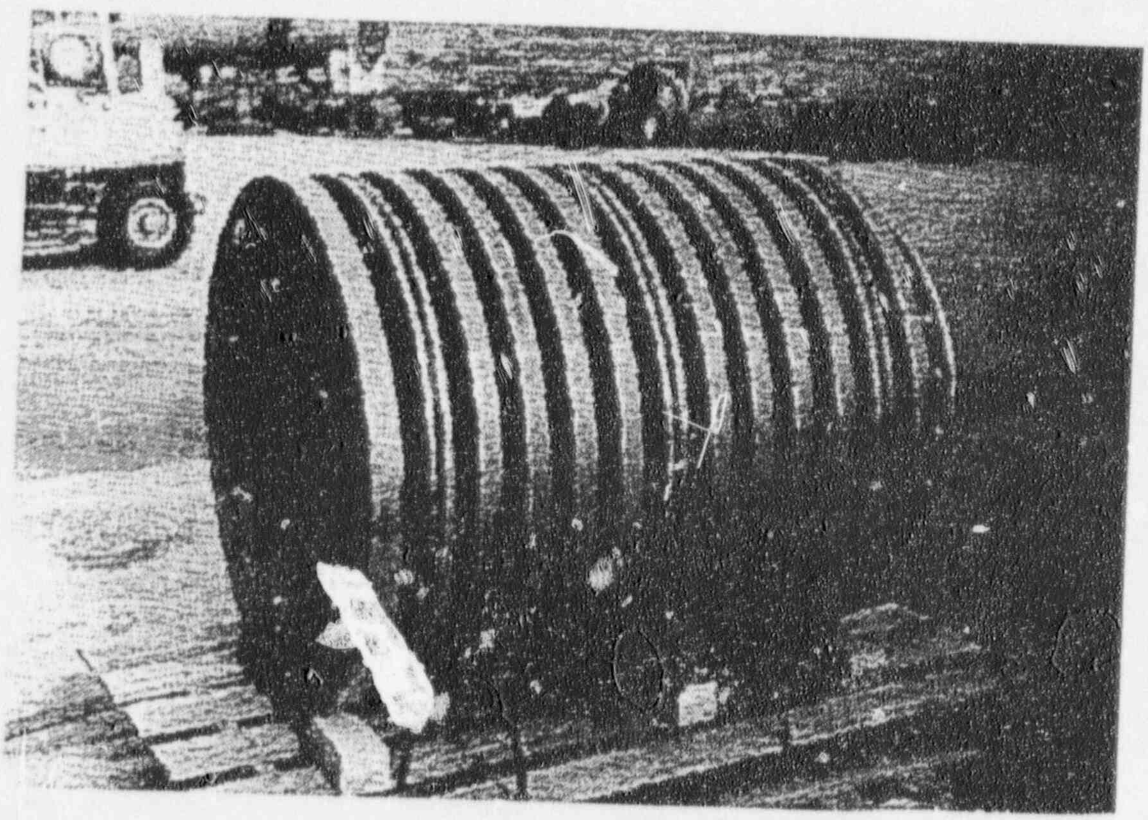

Figure 2-3 Photograph of Sure-Flow™ Strainer.

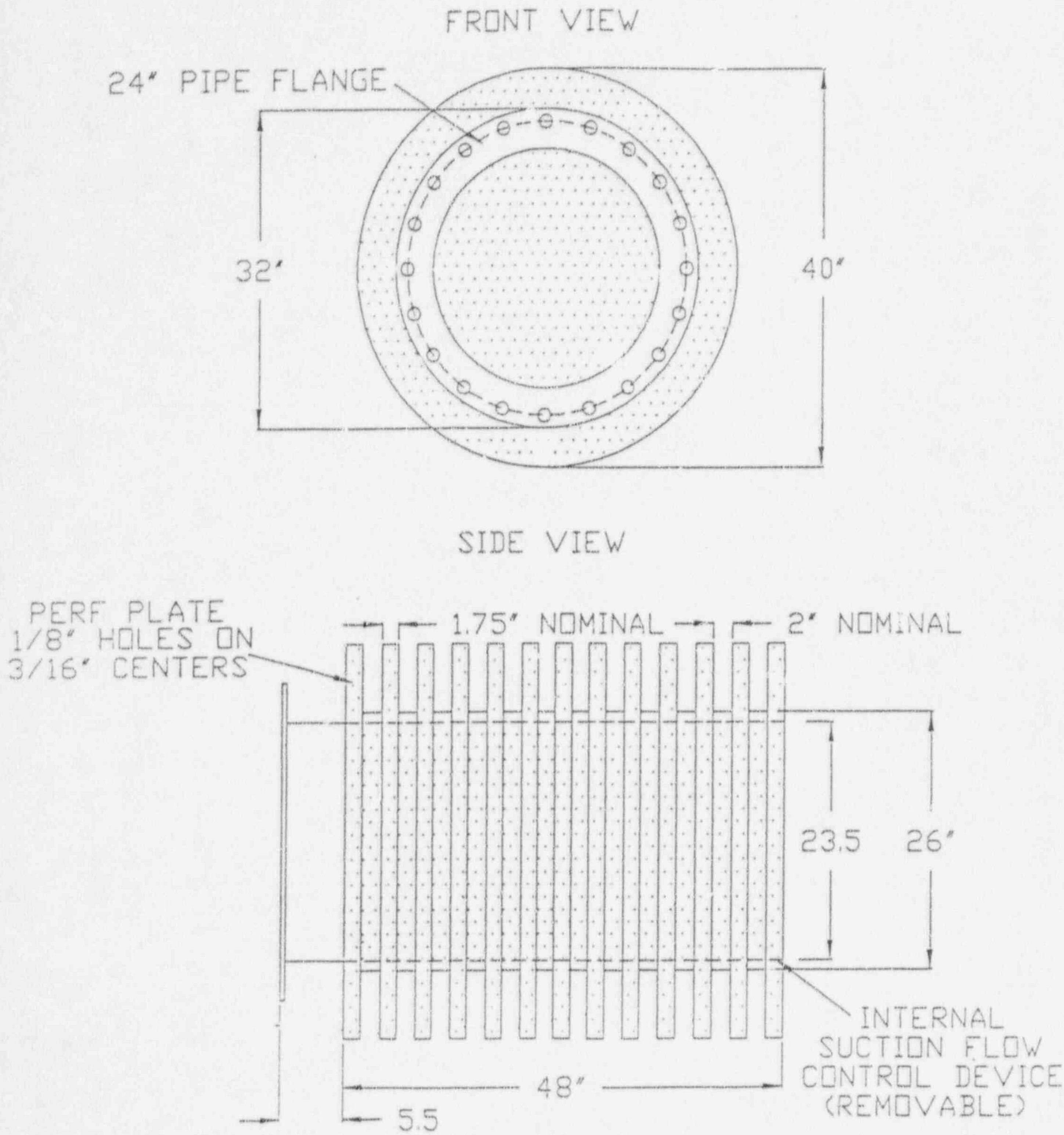

Figure 2-4 Sketch of Sure-Flow™ Strainer.

3

TEST MATRIX

The test matrix is shown below. It was modified from the preliminary matrix shown in the test plan based on PCI requirements.

Table 3-1
PCI Sure-Flow™ Strainer Test Matrix

Run	Mass Fiber (lbm)	Mass C.P. (lbm)	RMI (feet^2)	Comments
1	0	0	0	Clean head loss over full flow range.
2	25	100	800	RMI test with fiber, debris bed made at 5000 GPM.
3	100, 150, 200, 250, 300	0	0	Incremental Material Addition, debris bed was made at 4000 GPM for last addition.
4	100	100	0	Debris bed made at 5000 GPM
5	200	100	0	Boston ~~Commonwealth~~ Edison test, debris bed made at 4400 GPM and reduced to 4000 GPM.

The flow sweep at the end of each run was modified to provide additional data points for most runs as shown in Section 4 and in Appendix A.

4

TEST DATA

Table 4-1 summarizes the data collected from the test program. The table contains specific information about each test including run number, run date, flow rates tested, mass of insulation and corrosion products used (if applicable), amount of RMI, the average water temperature and the steady state differential pressure across the strainer (head loss) for that condition. All of the tabulated head loss values represent the head loss across the fiber/debris bed. The head loss of the clean strainer has been subtracted (except for the baseline, clean strainer case.)

Plots for each of the runs are included in Appendix A. The plots show the strainer differential pressure and the corresponding flow rate as a function of time. Material addition times and other run specific notes are indicated on the plots. The strainer differential pressure represents the head loss across the debris bed only, "clean" head loss has been subtracted out.

The data contained in the tables and the plots in the Appendix have been verified according to C.D.I. Quality Assurance procedures. Notes for each run are provided below.

Run PCI1

The first run was conducted from 1250 GPM to 10,000 GPM with no debris in the tank. From these data the clean head loss as a function of flow rate is determined so that the clean strainer head loss can be subtracted at any flow rate.

This clean head loss run was conducted with a lower water level than usual to check if air would be sucked in from the free surface. The centerline of the strainer was 95.5 inches above the tank floor, and the water level was measured at 165.8 inches by the DP1 transducer, which was mounted approximately 8 inches above the tank floor. With approximately 58 inches of water above the top of the strainer, no vortexing (or air being sucked into the strainer from the free surface) was visually apparent over the range of tested flowrates.

Run PCI2

This test was run with 25 pounds of fiber, 100 pounds of corrosion product and 800 square feet of RMI. The RMI was evenly divided into 3/8, 3/4, 1.5, 3 and 6 inch square pieces that were crumpled. After the corrosion products were added and allowed to circulate the fiber and RMI were added together.

Run PCI3

This test was conducted with fiber alone. The initial increment was 100 pounds, subsequent increments were 50 pounds. Fiber was added after approximately steady state head loss was reached for each increment. The head loss increased essentially linearly for each 50 pound increment, see Table 4-1 and Appendix A.

Run PCI4

This test was conducted with 100 pounds of fiber and 100 pounds of corrosion products.

Run PCI5

This run was conducted with 200 pounds of fiber and 100 pounds of corrosion products. Initially, the flow rate was set at 4400 GPM to form the debris bed. The flow rate was reduced to 4000 GPM to maintain the head loss below the maximum allowed for the strainer.

Table 4-1
Steady State Test Data

Run	Date	Flow Rate (GPM)	Insulation (lbs)	Corrosion Products (lbs)	RMI (ft^2)	Recipe %	Head Loss (in. H_2O)	Avg. H_2O Temp (°F)	Comments
PCI1	10/28	5000	-	-	-	-	0 [6]	69	Baseline clean strainer. [ ] - Denotes head loss across clean strainer.
PCI1	10/28	1250	-	-	-	-	0 [0.2]	69	

Table 4-1
Steady State Test Data

Run	Date	Flow Rate (GPM)	Insulation (lbs)	Corrosion Products (lbs)	RMI (ft^2)	Recipe %	Head Loss (in. H_2O)	Avg. H_2O Temp (°F)	Comments
PCI1	10/28	2500	-	-	-	-	0 [1]	69	
PCI1	10/28	3750	-	-	-	-	0 [3]	69	
PCI1	10/28	6250	-	-	-	-	0 [10]	69	
PCI1	10/28	7500	-	-	-	-	0 [15]	69	
PCI1	10/28	8750	-	-	-	-	0 [20]	69	
PCI1	10/28	10000	-	-	-	-	0 [24]	69	
PCI2	10/28	5000	25	100	800	-	28	70	
PCI2	10/28	2500	25	100	800	-	11	70	
PCI2	10/28	3750	25	100	800	-	19	70	
PCI2	10/28	6250	25	100	800	-	33	70	
PCI2	10/28	7500	25	100	800	-	35	70	
PCI2	10/28	8750	25	100	800	-	42	70	
PCI2	10/28	10000	25	100	800	-	52	70	
PCI2	10/28	5000	25	100	800	-	23	70	Δp increasing slowly.
PCI2	10/28	5000	25	100	800	-	29	70	Approximate steady state value after shutting off pump for one minute and restarting.

Table 4-1
Steady State Test Data

Run	Date	Flow Rate (GPM)	Insulation (lbs)	Corrosion Products (lbs)	RMI (ft^2)	Recipe %	Head Loss (in. H_2O)	Avg. H_2O Temp (°F)	Comments
PCI3	10/29	5000	100	-	-	-	73	71	
PCI3	10/29	5000	150	-	-	-	121	71	
PCI3	10/29	2500	150	-	-	-	56	71	
PCI3	10/29	3750	150	-	-	-	91	71	
PCI3	10/29	5000	150	-	-	-	119	71	
PCI3	10/29	5000	200	-	-	-	166	71	
PCI3	10/29	2500	200	-	-	-	74	71	
PCI3	10/29	3750	200	-	-	-	127	71	
PCI3	10/29	5000	200	-	-	-	166	71	
PCI3	10/29	5000	250	-	-	-	214	71	
PCI3	10/29	2500	250	-	-	-	100	71	
PCI3	10/29	3750	250	-	-	-	164	71	
PCI3	10/29	3750	300	-	-	-	194	71	
PCI3	10/29	4000	300	-	-	-	200	71	
PCI3	10/29	2500	300	-	-	-	116	71	
PCI3	10/29	4100	300	-	-	-	211	71	
PCI4	10/29	5000	100	100	-	-	147	70	
PCI4	10/29	2500	100	100	-	-	65	70	

Table 4-1
Steady State Test Data

Run	Date	Flow Rate (GPM)	Insulation (lbs)	Corrosion Products (lbs)	RMI (ft^2)	Recipe %	Head Loss (in. H_2O)	Avg. H_2O Temp (°F)	Comments
PCI4	10/29	3750	100	100	-	-	104	70	
PCI4	10/29	6200	100	100	-	-	177	70	
PCI4	10/29	6900	100	100	-	-	206	70	
PCI4	10/29	5000	100	100	-	-	144	70	
PCI5	10/30	4000	200	100	-	-	232	71	Removable perforated end plate covered with solid plate for run PCI5.
PCI5	10/30	2500	200	100	-	-	129	71	
PCI5	10/30	3000	200	100	-	-	157	71	
PCI5	10/30	3500	200	100	-	-	200	71	
PCI5	10/30	4000	200	100	-	-	231	71	

5

QUALITY ASSURANCE

All quality related test activities were performed in accordance with the Continuum Dynamics, Inc. Quality Assurance Manual, Revision 12 (Ref. 2). Quality related activities are those which are directly related to the planning, execution and objectives of the tests. Supporting activities such as test apparatus design, fabrication and assembly are not controlled by the C.D.I. Quality Assurance Manual. C.D.I.'s Quality Assurance Program provides for compliance with the reporting requirements of 10 CFR Part 21. All instrument certification and calibration, test procedures, data reduction procedures and test results will be contained in a Design Record File which (upon completion) will be kept on file at C.D.I. offices.

6

REFERENCES

1. Continuum Dynamics, Inc., Plan for Testing PCI SureFlow Strainer, Revision 1, 28 October 1996.

2. Continuum Dynamics, Inc., Quality Assurance Manual, Revision 12, October 1996.

A

DATA PLOTS

Plots of head loss across the debris bed and flow rate are shown for each test. For all runs, except PCI1, the clean head loss is subtracted from the total measured head loss to provide the head loss across the debris bed. Head loss is measured in inches of water and flow rate is measured in gallons per minute (GPM).

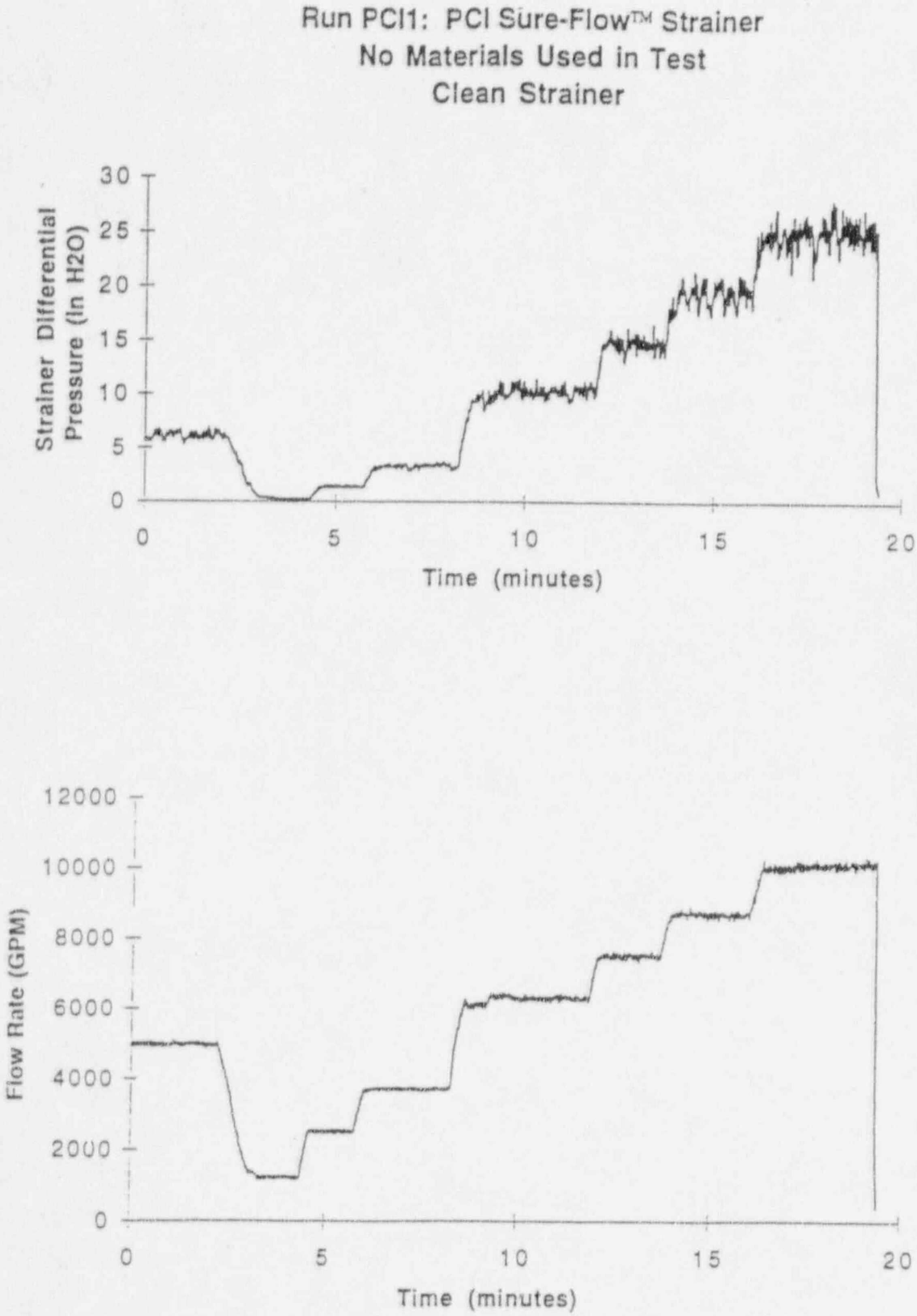

Figure A-1 Head loss and flow rate versus time for run PCI1.

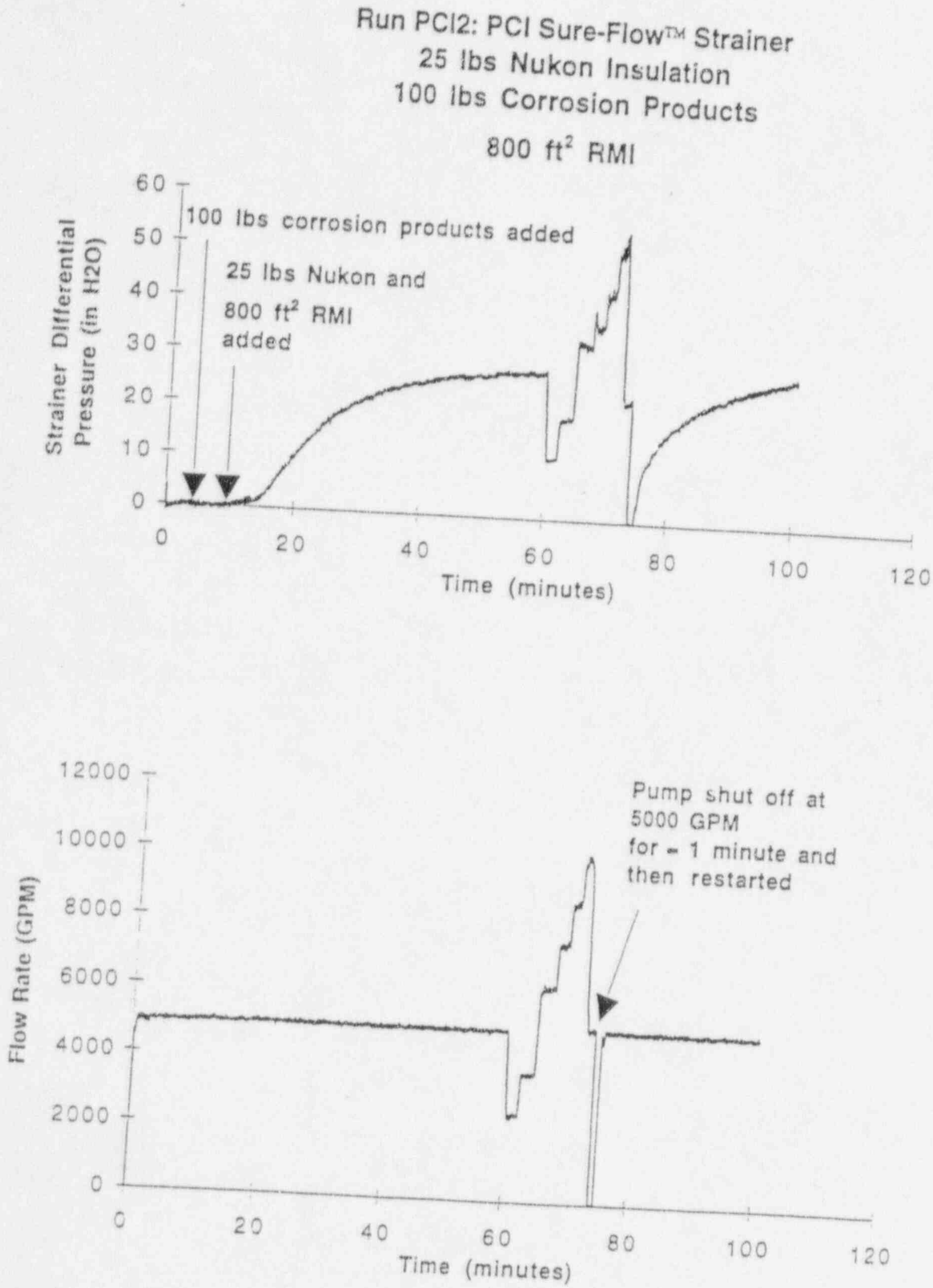

Figure A-2 Head loss and flow rate versus time for run PCI2.

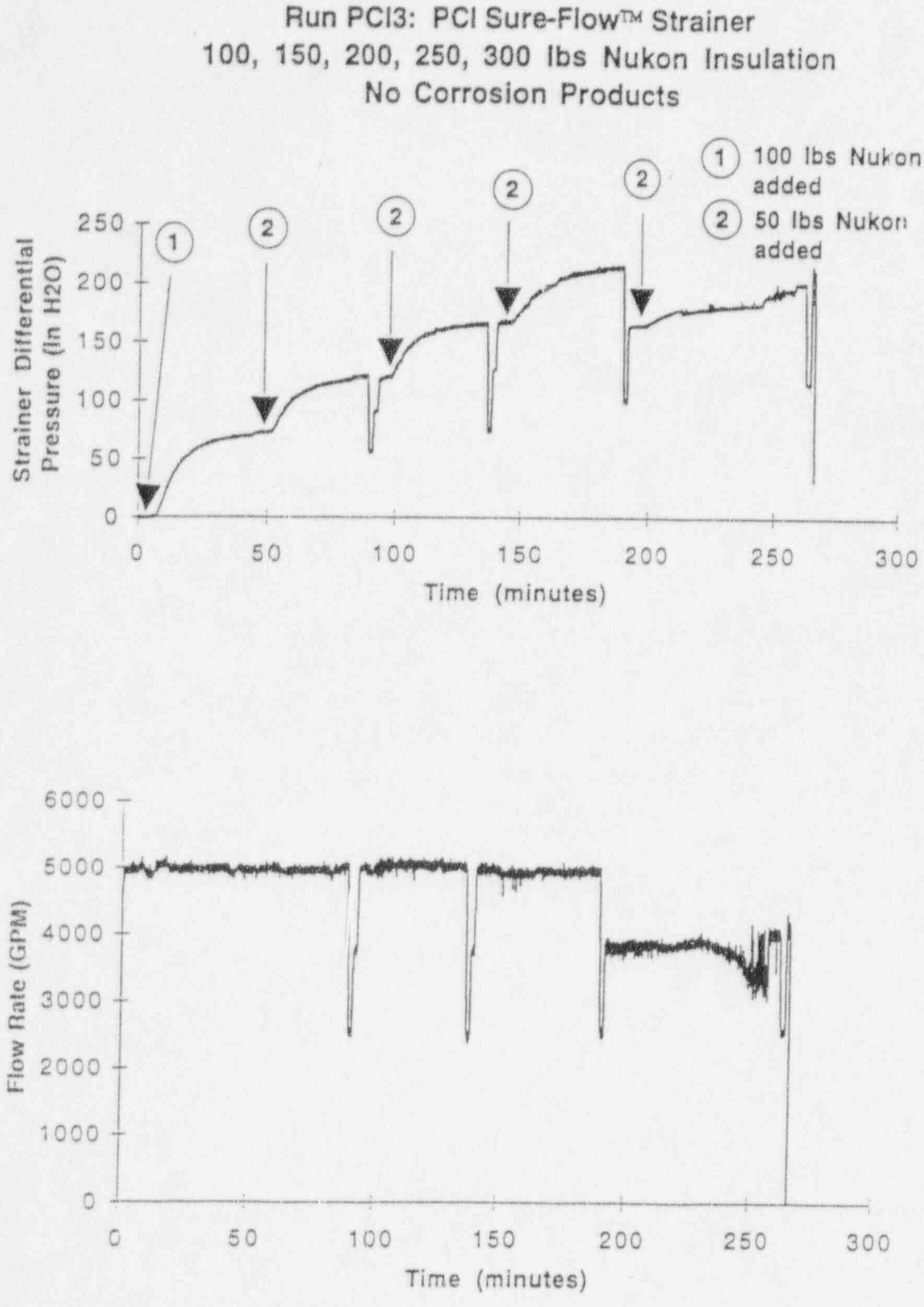

Figure A-3 Head loss and flow rate versus time for run PCI3.

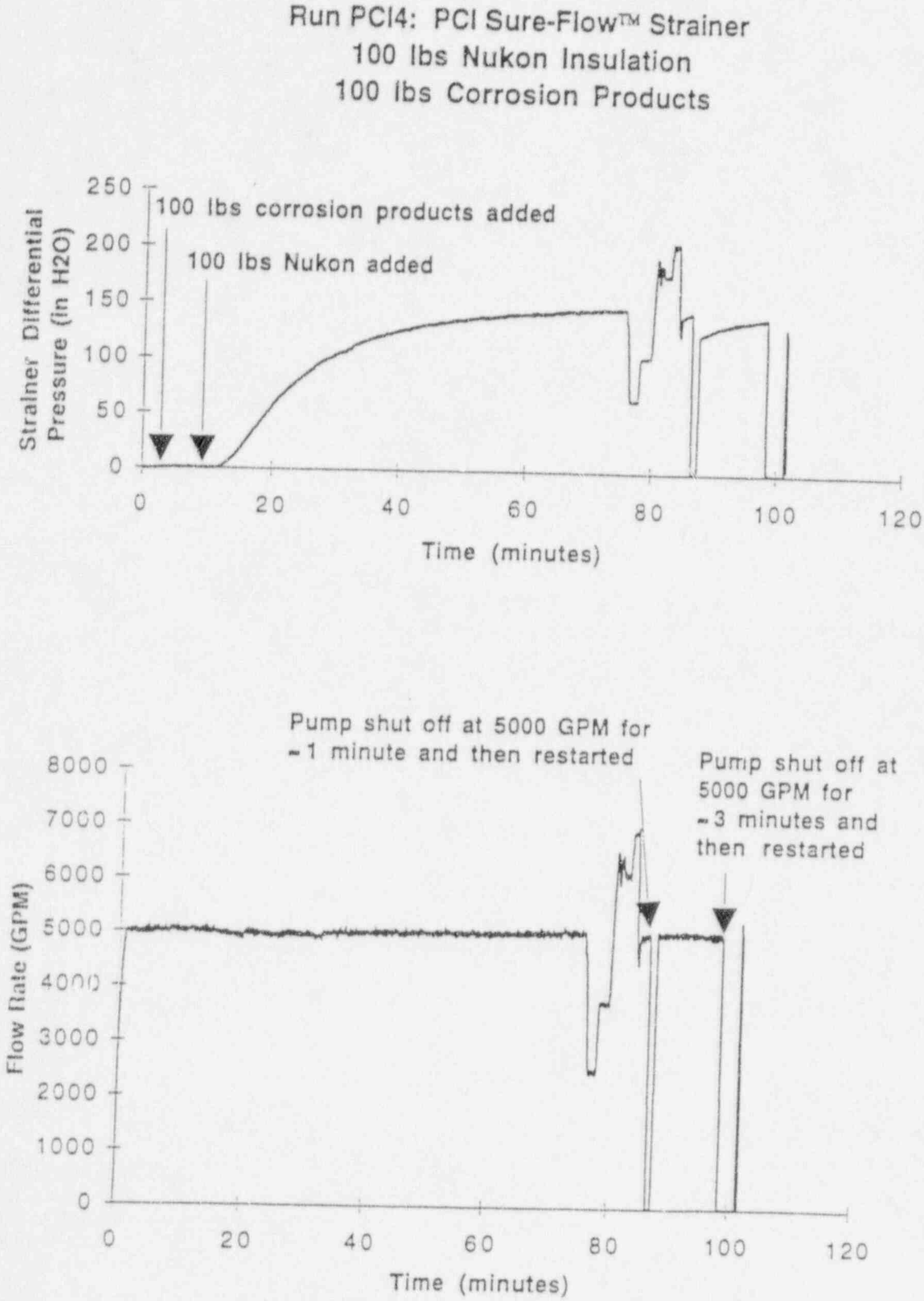

Figure A-4 Head loss and flow rate versus time for run PCI4.

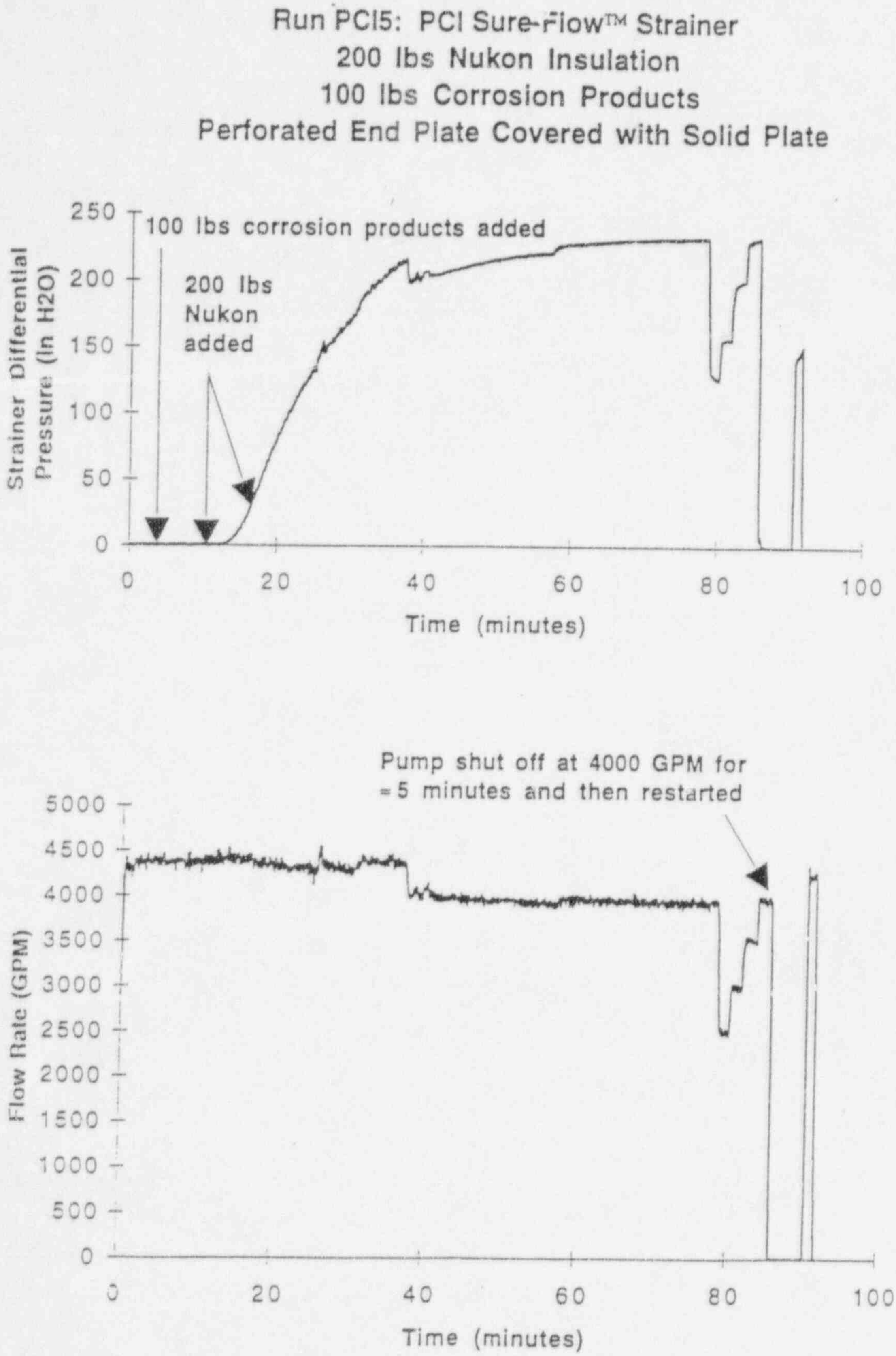

Figure A-5 Head loss and flow rate versus time for run PCI5.