BWR OWNERS' GROUP

Frederick P. "Ted" Schiffley, II
BWROG Chairman
Tel: (630) 657-3897
Fax: (630) 657-4328
frederick.schiffley@exeloncorp.com

c/o GE Hitachi Nuclear Energy, P.O. Box 780, 3901 Castle Hayne Road, M/C F-12, Wilmington, NC 28402 USA

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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Joe Golla (NRC)

Subject: BWROG ECCS Suction Strainers Bypass Test Plan

Reference:
1) BWROG ECCS Suction Strainer Issue Resolution Schedule Update, BWROG-10042, August 31, 2010
2) Summary of October 20, 2010 Public Meeting with the Boiling Water Reactor Owners' Group (BWROG), November 4, 2010 (ML103010393)

The purpose of this letter is to transmit for feedback the Boiling Water Reactors Owners' Group (BWROG) Emergency Core Cooling System (ECCS) Suction Strainers Committee's Strainer Bypass Test Plan, originally presented in Reference 1, and discussed more thoroughly at the October 20, 2010 public meeting (summarized in Reference 2). The Bypass Test Plan was noted as task 13.2.1.4, "Prepare test plan," in the level three BWROG program schedule attached to Reference 1. The BWROG requests the Nuclear Regulatory Commission (NRC) Staff's written feedback on the Bypass Test Plan within seven weeks (35 working days) of the Staff's receipt of this letter, an interval agreed upon during the October 20, 2010 public meeting (Reference 2). Future tasks depend upon receiving timely feedback from the Staff.

This Bypass Test Plan develops the plan for debris bypass testing to determine the quantity and characteristics of fibrous debris that can potentially bypass BWR ECCS suction strainers in a post-Loss of Coolant Accident (LOCA) environment. The results of the testing will be used to evaluate effects of debris traveling to components downstream of the strainers. The first step in considering these downstream effects is to generate a collection of data that represents the quantity and physical characteristics of the bypass debris associated with BWRs. The BWROG will collect such data by prototypical strainer testing.

NRC Staff feedback on this Bypass Test Plan is important for continuation of tasks under the Source Term and Downstream Effects – Components subprojects of the BWROG program plan (Reference 1).

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Please contact me or Ed Asbury, BWROG Project Manager, at (910) 819-7544, with any questions. Thank you.

Regards,

Frederick P. "Ted" Schiffley, II
Chairman
BWR Owners' Group

cc: M. H. Crowthers, BWROG Vice Chairman
C.J. Nichols, BWROG Program Manager
BWROG Primary Representatives
S.L. Scammon, BWROG ECCS Suction Strainers Committee Chairman
J. Golla, NRC

Commitments: None

Attachment: Bypass Test Plan

BWROG-TP-11-025
Revision 0
November 2011
BWROG-ECCS-TA13-002 Rev 2

BWROG ECCS Suction Strainer BWR Downstream Effects Bypass Test Plan

BWROG Emergency Core Cooling System Suction Strainers Committee's plan for measuring debris that bypasses the ECCS suction strainers after a LOCA

Author:	Rob Choromokos (Alion), Jeffrey Poska (Alion)
Committee Chair:	Steve Scammon (Energy Northwest)
Project Manager:	Rob Whelan (GEH)

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SCIENCE AND TECHNOLOGY

Document No: BWROG-ECCS-TA13-002	Revision: 2	Page: 1 of 33
Document Title: BWROG Downstream Effects Bypass Test Plan		
Project No: 07337-007		
Project Name: GEH: BWROG ECCS Suction Strainer Committee Project Technical Support		
Client: General Electric Hitachi (GEH)		

Document Purpose/Summary:

This document presents the Alion Test Plan for BWROG strainer fiber bypass testing utilizing the Alion Test Tank. Test Plan inputs are derived from BWROG-ECCS-TA13-001, BWROG ECCS Strainer Bypass Testing Technical Specification, Revision 0 [1] and email correspondence [11].

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Design Verification Method:

_X_ Design Review
___ Alternative Calculation
___ Qualification Testing

Professional Engineer (if required) Approval ____N/A____ Date ________

	Printed/Typed Name	Signature	Date
Prepared By:	Jeffrey J. Poska	[signature]	8-8-2011
Reviewed By:	Luke D. Bockewitz	[signature]	8-8-2011
Approved By:	Rob Choromokos	[signature]	8/8/2011

Form 3.3.1
Revision 2
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REVISION HISTORY LOG

Document No: BWROG-ECCS-TA13-002 Revision: 2

Document Title: BWROG Downstream Effects Bypass Test Plan

REVISION	DATE	Description
0	See Cover Page	Initial Issue.
1	See Cover Page	Incorporate BWROG comments as follows: changed Appendix 4 title in TOC, corrected acronyms, specified lb_m throughout document, corrected Hope Creek min. water volume in Appendix 4, clarified debris addition process in Section 3.0, added water chemistry discussion to Section 3.3, revised turbidity reference in Section 4.5 and added discussion, general formatting throughout.
2	See Cover Page	Incorporate Nuclenor data into Table 3.1, Appendix 1 and Appendix 4. Added reference. Updated formatting.

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ACRONYMS AND DEFINITIONS

°F	Degrees Fahrenheit
"	inches (length)
Alion	Alion Science and Technology
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners' Group
CS	Core Spray
dp	differential pressure
ECCS	Emergency Core Cooling System
gpm	gallons per minute (flow)
ft	Feet (of water)
ft/s	Feet per second
GE	General Electric
GSI	Generic Safety Issue
ITSO	Innovative Technology Solutions Operation
LOCA	Loss of Coolant Accident
M&TE	Measuring & Test Equipment
MSDS	Material Safety Data Sheet
NI	National Instruments
PCI	Performance Contracting, Inc.
psid	pounds per square inch differential
PWR	Pressurized Water Reactor
QA	Quality Assurance
RHR	Residual Heat Removal
SEM	Scanning Electron Microscope
USNRC/NRC	United States Nuclear Regulatory
ZOI	Zone of Influence

1.0 BACKGROUND

On November 27, 2007, the Nuclear Regulatory Commission (NRC) identified twelve areas of concern regarding the differences in treatment of containment strainer sump clogging issues for pressurized water reactors (PWR) and boiling water reactors (BWR) [2]. These were later reduced to seven key issues on April 10, 2008, and one of these areas concerns in-vessel downstream effects of debris that bypasses the ECCS suction strainers of BWRs [3]. The first step in considering these downstream effects is to generate a collection of data that represents the quantity and physical characteristics of the bypass debris associated with BWRs. A reasonable vehicle to collect such data is prototypical strainer testing.

Because the particulate portion of post-LOCA debris is much smaller than the perforations of ECCS suction strainers, the bypass testing will only consider fibrous debris (debris). 100% of the particulate debris is presumed to bypass the strainer.

This document develops the plan for conducting debris bypass testing for the purpose of determining the quantity and characteristics of fibrous debris that can potentially bypass BWR ECCS suction strainers in a post-LOCA environment.

2.0 TEST OBJECTIVES

The test objective is to quantify and characterize the fibrous insulation debris that would bypass the BWROG plants' ECCS suction strainers during the ECCS response timeline. Tests will be conducted that will determine the critical parameters that impact the quantity of debris that can be expected to bypass the strainers during ECCS operation. Tests will be structured to obtain data that can be used to develop an empirical tool that will allow BWROG's plants to determine the quantity of expected bypass debris with respect to known plant design and operating parameters. A test report which will describe the testing and the methodology required for bypass analysis will accompany the testing results.

The prototypical testing will provide adequate data for each BWR plant to determine:

- Fiber bypass quantity at specific times during ECCS operation
- Fiber bypass physical characteristics

3.0 TECHNICAL APPROACH

The BWROG has provided specific inputs relevant to their individual strainer designs and ECCS operation [1]. The methodologies used to develop the test matrix are described in Appendix 1.

The technical approach implemented in this test plan is to incrementally add fiber debris into the test tank and allow the debris to transport to a strainer. For each test, debris additions will be cumulative to facilitate the formation of a debris bed on the strainer. Each incremental addition will contribute to the debris bed thickness. Any fiber that bypasses the strainer (bypass fiber) shall be collected in a downstream filter system. Throughout the testing, filters must be changed after debris additions to determine the incremental effect of debris loading on bypass quantity. The filter system is configured with multiple elements in parallel to allow undisturbed flow through the strainer as flow is diverted between the filters. The filter bags shall be analyzed to measure and characterize the fiber bypass.

3.1 Strainer Designs

Plants within the BWROG have five separate ECCS strainer designs, sorted by vendor:

1. GE Stacked Disks with 3/32" or 1/8" holes in perforated plate
2. PCI Stacked Disks with 3/32" or 1/8" holes in perforated plate
3. Enercon Large Passive with 3/32" holes in perforated plate
4. CCI Cassette with 0.032" holes in perforated plate
5. ABB/CE Large Star with 1/16" or 1/8" holes in perforated plate

Testing shall determine the impact that different strainer designs have on bypass quantity. This will be accomplished by performing a series of bypass tests on a single strainer design, then repeating tests on an alternate design. A base strainer design will be selected. The base strainer will also serve as a constant parameter as other operating parameters are varied to determine their impact on bypass quantity. As multiple tests will initially be performed on the base strainer to vary individual test conditions, the base strainer can be selected in consideration of ease of assembly, disassembly and cleaning. A test article based on the GE stacked disk design with bolted connections that allow disassembly is desirable for use as the base strainer. The test article can be configured with a nominal screen surface area of approximately 23 ft^2 utilizing 1/8" holes. From the compiled plant data [1], it is observed that this design is applied to the largest range of plant fiber concentrations within the suppression pools which includes the lowest concentration of fiber. Appendix 1 includes a summary table of fiber concentrations within the BWROG suppression pools for each of the strainer designs. The proposed surface area of 23 ft^2 will facilitate modeling of the low fiber concentrations associated with the GE strainer. Other strainer designs are applied to plants with greater fiber concentrations and can be tested with prototypes configured with approximately 40 ft^2 of surface area.

Upon completion of the test series that determines the impact of varying individual test conditions, tests will be performed on a similar GE test strainer with 3/32" perforations. Comparison of the results will illustrate the degree to which hole size affects bypass quantity. Finally, an alternate design represented by the Enercon strainer shall be tested to isolate the impact of strainer geometry on bypass quantity. The Enercon strainer is desirable as an alternate design due to the contrast in geometry with respect to the GE and other strainer designs.

3.2 Flow Rate

A range of flow rates are applied during testing to determine the impact of velocity on bypass quantity. The test flows selected include high flow conditions that yield approach velocities near the upper range of the plant strainer approach velocities, and lower flows. The approach velocity is calculated by dividing the flow rate by the gross unobstructed screen area. The bypass quantities resulting from each flow rate tested shall be examined upon completion of the test to determine if this individual attribute has an effect on the results. If bypass quantity is shown to be related only to the mass quantity of fiber that reaches the strainer without significant effect from the specific velocity, then a single representative flow will be selected for the remaining tests. This shall be illustrated by measuring bypass quantities that result from the equivalent mass transport quantities of fiber occurring under different flow conditions. Since approach velocity of a given strainer is determined by flow and surface area, the specific test flows are identified in Section 3.6 below.

3.3 Water Chemistry and Temperature

Plant water chemistry has been shown to result in chemical effects that significantly reduce the porosity of the debris bed. The addition of chemical compounds that form on the strainer is expected to inhibit the ability of debris to bypass the strainer. However, it is not the objective of this test to evaluate the impact of chemical effects on fiber bypass. Therefore, specific plant suppression pool chemistry will not be established in the test medium. The test will be run with municipal water that has been filtered through a commercial 5-micron filter prior to the introduction of fiber. This process is intended to minimize the trace quantities of minerals and particulates that are typically found in potable water. Any remaining material that is deposited on the test filers would result in slightly conservative results.

Temperatures lower than those expected in post LOCA environments will result in lower settling velocities yielding conservative results. Therefore, the tests may be performed at ambient temperature conditions. Temperature shall be monitored but not controlled throughout the test.

3.4 Debris Type

A range of fibrous insulation types are present in BWRs. The differences in bypass quantity between high and low density fiberglass will be demonstrated by performing two similar tests with the two types of fiber. Pool volume, flow, debris concentration, turbulence and other test parameters will then be held constant. If the compared results are not within the tolerance identified in Section 7.1.2, then a test matrix will be developed to test the specific type of debris associated with each set of plant conditions that are determined to affect bypass quantity. For example, if tests show that the type of fiber has a significant impact on bypass quantity, then additional tests will be performed to determine bypass data for specific types of fiber. However, if bypass quantities differ only slightly between the low and high density tests, a conservative selection may be made for subsequent tests. Debris types and parameter of concern are included below.

Table 3-1: Debris Types and Parameters [2]

Debris	Plants with debris *count*	As-fabricated Density[1] *lb_m/ft^3*	Characteristic Diameter[1] *micron*
Rockwool	3	4 to 10	5 to 7
Fiberglass	7	2.7 to 5.5	6.75 to 8.25
Thermal Wrap	3	2.4	5.5
Nukon	23	2.4	7
Temp-Mat	6	11.8	9
Calcium Silicate	3	14.5	2 to 100
K-wool	1	TBD	TBD
Min-K	1	8 to 16	0.1

[1] NEI 04-07, Volume 1 [10]

Note: There is limited application of Asbestos cloth, Fiber-Mat and lead blanket covers. The range of materials used in test series C1-C5, D1 and D2 is presumed to provide a sufficiently diverse range of tested fiber characteristics.

As shown in the above table the lowest density fiberglass used throughout the BWRs is Nukon (2.4 lb_m/ft^3). Although Calcium Silicate and Min-K have the highest as-fabricated densities, their microporous compositions include additional solids that fail as particulate. Microporous insulation was treated as a particulate debris source during PWR ECCS strainer testing, (i.e., the fiber constituent was not considered during thin bed formation or bed thickness calculations). Due to the small size of failed particulates (10 micron), it is assumed that 100% of microporous debris can bypass the strainer. Because of these reasons, microporous insulation will be excluded from this series of bypass testing. In contrast, Temp-Mat is all fibrous material. Therefore Temp-Mat (11.8 lb_m/ft^3) will be selected as the high density fiberglass test material. Additionally, Rock Wool will be tested to provide an intermediate material density.

3.5 Debris Load

Fibrous debris quantities at BWR plants range from latent fiber only to large amounts of fiberglass. Fiber bypass, however, is not expected to occur after the debris bed completely covers the strainer surface. Once a complete fiber bed has formed on the strainer (i.e., no clean screen area exists), that fiber bed will act as its own filter and limit further bypass. Bypass test C2 shall be performed during the variable pool concentration series (Tests C1-C5) and will establish the limiting debris load beyond which fiber does not bypass the strainer surface. The individual fiber quantities collected after each step shall be plotted to illustrate that the total debris load on the strainer is sufficient to preclude further bypass. The limiting debris load observed will become the maximum debris load used in the subsequent test sequences.

3.6 Approach Velocity

By review of Appendix 4, the maximum approach velocities for the BWR plants that utilize fiberglass insulation range from 0.00564 ft/s to 0.117 ft/s [1]. Plants that reported flows and strainer screen areas resulting in higher approach velocities are also reported not to use fiberglass insulation. The actual ECCS pumps installed in the plants are capable of operating at very high delivery limits. Due to the high head losses that will likely result from the filtration system used to collect the bypass fiber in the test lab, the extreme upper limits of the plant velocities may not be easily replicated. However, a sufficient range of low to high test velocities can be achieved to develop a plot that represents the relationship between approach velocity and the quantity of bypass fiber. As observed in the test matrix the range of approach velocities will be 0.02 ft/s to 0.06 ft/s. This range reflects the actual approach velocities of the majority of plants, and can be use to determine that desired relationship between velocity and bypass quantity.

3.7 Debris Concentration

The individual batches of fiber introduced to the tests shall be sized with respect to the test pool volume to yield fiber concentrations that represent the range of plant concentrations. Tests C1-C5 described in Section 5.0 specify multiple batch additions that each result in nominal bed thicknesses ranging from 1/64" to 3/4". The extremes of this range represent the lowest concentration of fiber in the BWROG suppression pools, to a high concentration that is expected to exceed the limiting bypass fiber quantity. If it is determined in Test C2 that the limiting bypass quantity results in a bed thickness greater than ¾", then the upper concentration test quantity shall be adjusted accordingly. Results of bypass quantities collected from this sequence of tests shall be evaluated to determine if the specific attribute of debris concentration impacts the bypass quantity.

3.8 Pool Turbulence

The pool turbulence in the wet well/suppression pool depends on the designed LOCA responses and the duration of blowdown, condensation oscillations and chugging during the high energy phase of the accident. Each test will begin by modeling a high turbulence phase using propeller type mixers. This will inhibit any bed formation of fiber on the strainer only for the duration of the high turbulence stage, which is considered to occur for 65 seconds after the first debris introduction [1]. This duration represents the combined interval of condensation oscillation, which ends 35 seconds after LOCA initiation, plus an additional 30 seconds of chugging for large break LOCA's.

Simulating turbulence in this way is conservative from the standpoint that while the strainer is mechanically cleared of debris, more bypass would be expected to reach the filter bags due to the absence of the filtering effect that results from the formation of a fibrous debris bed on the strainer.

Other pool turbulence shall be provided by submerged mixing motors (at a lower speed) and provide enough pool turbulence to suspend the debris off of the Test Tank floor without stripping fiber off of the strainer. It is necessary to keep fiber in suspension during the test as the final tool used in determining plant bypass quantities will be based on the mass of fiber transported to the strainer during the tests. This level of turbulence shall be maintained until the completion of each test.

3.9 Bypass Fiber Collection

For fibrous insulation testing, 5-micron nominal bags with a 90% capture efficiency, procured form McMaster-Carr, or equivalent, shall be used (item # 162K44 5-micron polyester felt bags). Fibrous debris used in testing has characteristic diameters greater than 5 microns. These larger diameters combined with the random orientation of the fiber as it contacts the filter bag suggest that the capture efficiency will be greater than the rated value. Therefore, as a measure of conservatism, a 5% increase may be applied to the measured bypass quantities.

4.0 TEST DESCRIPTION

Prior to each test, the appropriate number of filter bags shall be prepared by drying in an oven at 200 °F. The pre-drying establishes a baseline weight to be measured. (This pre-weight is the weight of the clean filter bag without any fiber prior to use during testing and shall be compared to the weight of the filter bag after testing to calculate the quantity of bypass fiber captured.)

The fiber debris that is to be used for testing shall be processed into fibrous fines by shredding, boiling, and beating [4].

The Alion Test Tank shall be thoroughly cleaned prior to each test. The appropriate hardware (suction strainer prototype, plenum, sparger, walls) shall be installed, and the tank shall be filled with potable tap water to the specified level for a nominal 2500 gallons. This volume is selected to facilitate laboratory equipment capacity and provide the desired relationships between debris volume and test pool volume.

The filter bags (designated as "F" in Figure 4-1) shall be installed into the housings, and at the test flow rate, they shall be valved inline. After 5 pool turnovers, one bag shall be removed and marked CONTROL. This bag will serve as the baseline for future drying times and background weight gain. It should be understood that drying filter bags that have accumulated bypass fiber will likely require additional drying time.

At the appropriate flow rate and turbulence, a measured amount of fiber debris shall be added at a specific introduction rate per the test matrix. The debris will be allowed to reach the strainer via turbulence and approach velocities for a given amount of time as defined by the number of pool turnovers at the specified flow rate. All water passing through the strainer shall be filtered by the pre-dried filter bags. More debris shall be added and allowed to reach the strainer per the test matrix. Simulation of high energy turbulence will end after 65 seconds from initial debris introduction.

After all debris has been added in accordance with the test matrix and the required number of pool turnovers has been achieved, the filters are valved out and the filter bags are removed. (Note that this step may occur on occasions earlier than the test end for sake of capturing filter bypass trends vs. time.) The used filter bags are put into an oven and allowed to dry. Each is weighed multiple times until the weight remains stable at the baseline oven temperature.

The bypass fiber can then be calculated by subtracting the baseline CONTROL filter weight gain and the pre-dried filter weight from the post-test dried weight of each bag. The fibers can be physically analyzed after removal from the bag after the mass gain has been determined.

The tank is then cleaned and reset, and new filter bags and fiber debris are prepared for the next test.

4.1 Apparatus

The testing will be performed in the Alion Test Tank at the Alion Hydraulics Laboratory located in Warrenville, IL. The Test Tank allows the measurement and control of flow rate and water temperature. Differential pressure across the strainer, differential pressure across the filter bags, and downstream water turbidity can be measured in real-time. The data acquisition system is comprised of National Instruments FieldPoint hardware and LabVIEW software. The water downstream of the strainer is passed through the filters before being injected into the tank via a sparger system, which aids in debris suspension. Mixing motors provide the turbulence to simulate blowdown, condensation oscillations and chugging, and to keep the debris suspended in the pool after the high energy phase.

A diagram of a typical test tank instrumentation setup is illustrated below.

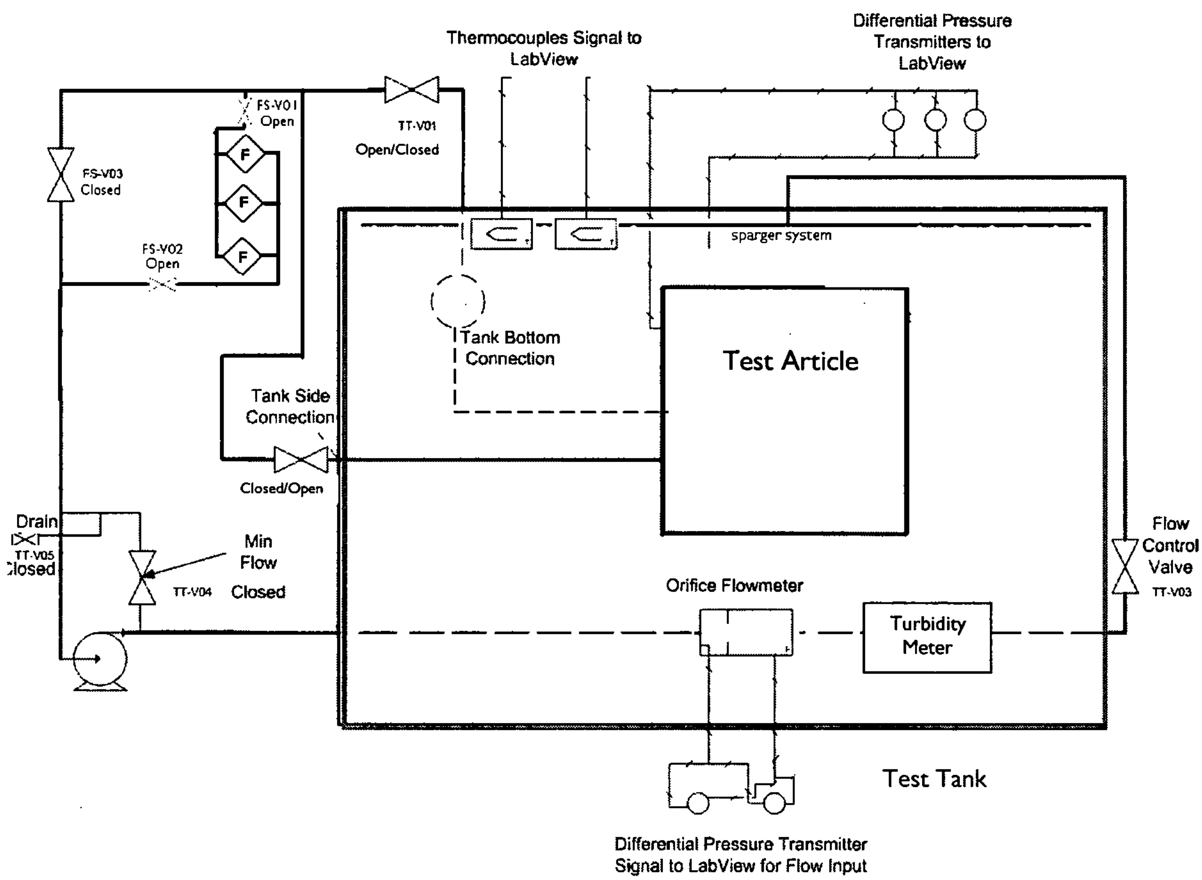

Figure 4-1: Hydraulic Test Tank Diagram

4.2 Supporting Equipment

The filter bags will be dried in ovens prior to and after testing. The fiber bypass weight gain will be measured with analytical balances verified daily with calibrated mass sets. The physical characteristics of the fiber bypass will be analyzed via microscopy, including the application of a scanning electron microscope for fiber length measurements and imaging.

As-received fiber insulation will be prepared into fines using a leaf shredder (with Briggs and Stratton 1450 Series 305cc engine), large boiling pots, and electric paint mixer drill attachments [4]. Stages of each debris prep method are timed with traceable timers (stopwatches).

4.3 Filter Preparation

For fibrous insulation, McMaster-Carr 5162K44 5-micron polyester felt bags will be used. The filter bags can be dried right out of the box after inspection for tears or damage and photographing. Each filter bag should be labeled with an identifier (A, B, etc.) on the cloth handle, and a drying log should be initialized for each upon placing into an oven. The oven must be maintained around 200 °F for a period of 24 hours to ensure complete stabilization of the baseline environment. Two consecutive measurements within 0.05 g over 4 hours signal that the filter bag is ready for use. Upon this stable measurement, the bag should be removed from the oven and placed in a clean, labeled sample bag until testing.

This process must be repeated for all filter bags used in testing.

4.4 Fiber Preparation

Alion fibrous debris requiring in-house preparation must follow procedure ALION-SPP-LAB-2352-22 [4]. This procedure produces the required size distribution and fiber fines that are easily transportable and readily disperse in the testing medium. All fiber blankets will be double-shredded with a leaf shredder, weighed out into the proper batches, and then boiled for 10 minutes. Fiber fines, as described in the debris preparation procedure, will be further processed by adding 4 gallons of water to ¼ lb_m of fiber and beating with a paint stirrer for a minimum of 4 minutes.

Representative samples of fiber shall be examined and photographed using a light-board or equivalent device to ensure that the fiber preparation is consistent. By observation, the prepared fiber should reflect the conditions illustrated in Appendix 3 for fiber classes 1-3.

4.5 Test Tank Preparation

Each article to be tested should be installed as depicted in Section 4.1. Appropriate M&TE should be installed as required in Section 6.2 and verified per ALION-SPP-LAB-2352-13, Test Equipment Verification Procedure [7].

A sparger system may be installed on the return line to aid in the suspension of the debris within the water. The sparger is installed to maximize debris suspension in the tank. The sparger shall not disturb the debris bed around the strainer.

The mixing motors shall be installed near the bottom and in the corners of the tank.

The differential pressure tubing, both the High and Low lines, must be securely fastened inside the tank to prevent vibrations that cause noisy signals. Furthermore, the Low side must be securely fastened to the plenum/strainer to prevent ambient leakage.

The National Instruments' (NI) LabVIEW™ data acquisition software must be programmed to match the test parameters in the Test Matrix and Section 6.2, such as strainer area and correct orifice plate conversion. English units shall be displayed and recorded in the test logs and data files.

The Test Tank must be filled according to ALION-SPP-LAB-2352-44 [6].

The Test Tank must be thoroughly cleaned prior to each test to prevent contamination of the filter bags; therefore, in addition to following ALION-SPP-LAB-2352-45, Test Tank Draining and Cleaning Procedure [9], the tank system must be filtered with 5-micron filters after all the hardware is installed and prior to testing to remove any remaining particulates or fibers. As all tests are of a relatively short duration (i.e. < 24 hours), significant accumulations of any remaining minerals in the filter bags are not expected. The "pretest" filters do not require preparation described in section 4.3 and must be removed prior to test start. The turbidity of the clean system must be less than 5 NTU.

4.6 Hydraulic Test Conditions

Testing shall be conducted per the Test Matrix. The hydraulic conditions are maintained by controlling the test flow rate and turbulence conditions in the Test Tank.

4.7 Testing

At all times the Lab Safety Procedure, ALION-SPP-LAB-2352-21 [5] shall be followed.

4.7.1 Test Control

All testing actions and control must be noted in the test log. This includes flow adjustments, water sampling, debris addition (beginning and completion), stirring (including the duration of the stir), filter removal and installation, and all other acts that affect the testing environment. The test logs shall describe everything about the test without recourse to the test engineer.

The flow rate of the system shall be maintained at ±10 gpm of the prescribed value.

Test acceptance criteria for is given in Section 7.0.

Debris shall not be allowed to settle in the Test Tank. If debris settling begins to occur, additional agitation is required to ensure that non-representative debris settling is minimized. Trolling motors and/or a wooden paddle may be used to suspend settled debris, although agitation must not disturb the debris bed on or around the strainer. Any settled debris remaining on the floor area shall be photographed and noted in the test log.

To simulate the high energy phase of the postulated suppression pool conditions, the mixing motors shall be set to a high enough speed to inhibit bed formation on the strainer. After the initial 65-second period, the fibers shall then be allowed to migrate back to the strainer under normal flow conditions.

The entire flow downstream of the strainer shall be passed through a filter cartridge assembly during bypass testing.

Water temperature shall be monitored but not controlled during testing.

4.7.2 Control Filter Bag

At the beginning of testing before debris introduction, a clean filter bag should be subjected to the test flow rate for 5 pool turnovers to gather a possible baseline background mass gain caused by the collection of any particulates remaining in the water after tank cleaning. This Control filter bag must be processed per Section 4.7.6.

4.7.3 Debris Introduction

See Section 4.4 for debris preparation requirements. Batches of fiber will be added per the Test Matrix. To prepare for fibrous debris addition for the test, all of the debris for the test must be mixed into small buckets with adequate water using a paint stirrer to form a slurring to ensure complete debris addition. Debris will be introduced into the tank at the rate specified in the Test Matrix, and into area of high velocities near the sparger return line. Adjustable tank internal mixing will be added to areas of low velocities.

4.7.4 Pool Turnovers and Debris Interval Timing

The amount of fiber that bypasses the strainer screen will be determined relative to the quantity of fiber that is transported to the strainer. To ensure that all fiber added to each test step reaches the strainer, an interval of 5 pool turnovers at the specified test flow rate will be allowed. This pool turnover quantity parallels the NRC guidance related to PWR head loss testing. Specifically, this guidance states that five pool turnovers are adequate to ensure filtration when the bed filtration efficiency is near one. Although the objective is different between the tests, this guidance can be implemented to provide reasonable assurance that the full volume of the test tank has flowed through the strainer. The multiple volume circulations of the test pool, combined with the use of mixing devices, will ensure that all debris reaches the strainer surfaces. Pool turnovers are calculated based on pool volume including piping and the nominal flow rate during the test.

4.7.5 Filter Bag Removal

Filter swapping, which is the removal of one filter bag at a specified time and replacement with a clean, pre-dried filter bag, can be accomplished whenever necessary per the Test Matrix. The filter bags have a maximum pressure rating of 10 psid. If the pressure begins to approach this value, the filter bags should be removed and replaced with clean, pre-dried filter bags.

4.7.6 Filter Bag Processing

Upon removal from the test system, the filter bag shall be photographed inside and out. It shall be allowed to drip-dry for approximately five minutes, and then transported to the drying oven. The drying log must reflect when the filter began drying after testing. The oven must be maintained at a nominal 200 °F for a period of 48 hours to ensure complete drying. Three consecutive measurements within 0.05 g of each other over 4 hours signals that the filter bag is dry, and that the weight gain is the collected fiber and not non-evaporated water. Upon this stable measurement, the bag should be removed from the oven and placed in a clean, labeled sample bag until further analysis.

This process must be repeated for all filter bags used in testing.

4.7.7 Fiber Characterization

After the filter bags have been processed per Section 4.7.6, any required fiber samples can be removed from the filter bags. Any convenient means to remove a fiber sample from the filter bag may be used, however, care must be taken not to artificially contort or destroy the fibers during removal.

To characterize the physical parameters of the bypass fiber, samples will be sent to an SEM lab for fiber length measurements. The results will include calculated averages as well as magnified images of samples.

5.0 TEST MATRICIES

The debris loads and other test parameters are indicated below. Note that information shown in grey may not be required as illustrated by determination of the limiting bed thickness that precludes further bypass.

5.1 Debris Concentration Tests C1-C5

Table 5-1: Test C1

Debris Concentration Test C1 on GE Stacked Disk Strainer (1/8" hole size) (Nukon, 2500 gal. Tank, 412 gpm, 23 ft² Screen)						
Test # C1 *(Steps)*	Batch Quantity *(lbm)*	Individual Batch Concentration *(ft³/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
C1.0	0	0	0	0.04	Pretest C1	412
C1.1	0.08	0.000013	1/64	0.04	-	412
C1.2	0.08	0.000013	1/32	0.04	-	412
C1.3	0.08	0.000013	3/64	0.04	-	412
C1.4	0.08	0.000013	1/16	0.04	C1.4	412
C1.5	0.08	0.000013	5/64	0.04	-	412
C1.6	0.08	0.000013	6/64	0.04	-	412
C1.7	0.08	0.000013	7/64	0.04	-	412
C1.8	0.08	0.000013	1/8	0.04	C1.8	412
C1.9	0.08	0.000013	9/64	0.04	-	412
C1.10	0.08	0.000013	10/64	0.04	-	412
C1.11	0.08	0.000013	11/64	0.04	-	412
C1.12	0.08	0.000013	12/64	0.04	-	412
C1.13	0.08	0.000013	13/64	0.04	-	412
C1.14	0.08	0.000013	14/64	0.04	-	412
C1.15	0.08	0.000013	15/64	0.04	-	412
C1.16	0.08	0.000013	1/4	0.04	C1.16	412
C1.17	0.08	0.000013	17/64	0.04	-	412
C1.18	0.08	0.000013	18/64	0.04	-	412
C1.19	0.08	0.000013	19/64	0.04	-	412
C1.20	0.08	0.000013	20/64	0.04	-	412
C1.21	0.08	0.000013	21/64	0.04	-	412

(Table 5-1, continued)

Test # C1 *Steps*	Batch Quantity *(lb_m)*	Individual Batch Concentration *(ft^3/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
C1.22	0.08	0.000013	22/64	0.04	-	412
C1.23	0.08	0.000013	23/64	0.04	-	412
C1.24	0.08	0.000013	24/64	0.04	-	412
C1.25	0.08	0.000013	25/64	0.04	-	412
C1.26	0.08	0.000013	26/64	0.04	-	412
C1.27	0.08	0.000013	27/64	0.04	-	412
C1.28	0.08	0.000013	28/64	0.04	-	412
C1.29	0.08	0.000013	29/64	0.04	-	412
C1.30	0.08	0.000013	30/64	0.04	-	412
C1.31	0.08	0.000013	31/64	0.04	-	412
C1.32	0.08	0.000013	1/2	0.04	C1.32	412

Table 5-2: Test C2

Debris Concentration Test C2 on GE Stacked Disk Strainer (1/8" hole size) (Nukon, 2500 gal. Tank, 412 gpm, 23 ft^2 Screen)						
Test # C2 ***(Steps)***	**Batch Quantity** ***(lb_m)***	**Individual Batch Concentration** ***(ft^3/gal)***	**Theoretical Bed Thickness (nominal)** ***(in)***	**Approach Velocity** ***(ft/s)***	**Filter ID** ***(End of Step)***	**Flow** ***(gpm)***
C2.0	0	0	0	0.04	Pretest C2	412
C2.1	0.29	0.000048	1/16	0.04	C2.1	412
C2.2	0.29	0.000048	1/8	0.04	C2.2	412
C2.3	0.29	0.000048	3/16	0.04	C2.3	412
C2.4	0.29	0.000048	1/4	0.04	C2.4	412
C2.5	0.29	0.000048	5/16	0.04	C2.5	412
C2.6	0.29	0.000048	3/8	0.04	C2.6	412
C2.7	0.29	0.000048	7/16	0.04	C2.7	412
C2.8	0.29	0.000048	1/2	0.04	C2.8	412
C2.9	0.29	0.000048	9/16	0.04	C2.9	412
C2.10	0.29	0.000048	5/8	0.04	C2.10	412
C2.11	0.29	0.000048	11/16	0.04	C2.11	412
C2.12	0.29	0.000048	3/4	0.04	C2.12	412

Table 5-3: Test C3

Debris Concentration Test C3 on GE Stacked Disk Strainer (1/8" hole size) (Nukon, 2500 gal. Tank, 412 gpm, 23 ft² Screen)						
Test # C3 *(Steps)*	Batch Quantity *(lbm)*	Individual Batch Concentration *(ft³/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
C3.0	0	0	0	0.04	Pretest C3	412
C3.1	0.58	0.000096	1/8	0.04	C3.1	412
C3.2	0.58	0.000096	1/4	0.04	C3.2	412
C3.3	0.58	0.000096	3/8	0.04	C3.3	412
C3.4	0.58	0.000096	1/2	0.04	C3.4	412
C3.5	0.58	0.000096	5/8	0.04	C3.5	412
C3.6	0.58	0.000096	3/4	0.04	C3.6	412

Table 5-4: Test C4

Debris Concentration Test C4 on GE Stacked Disk Strainer (1/8" hole size) (Nukon, 2500 gal. Tank, 412 gpm, 23 ft² Screen)						
Test # C4 *(Steps)*	Batch Quantity *(lbm)*	Individual Batch Concentration *(ft³/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
C4.0	0	0	0	0.04	Pretest C4	412
C4.1	1.15	0.00019	1/4	0.04	C4.1	412
C4.2	1.15	0.00019	1/2	0.04	C4.2	412
C4.3	1.15	0.00019	3/4	0.04	C4.3	412

Table 5-5: Test C5

Debris Concentration Test C5 on GE Stacked Disk Strainer (1/8" hole size) (Nukon, 2500 gal. Tank, 412 gpm, 23 ft² Screen)						
Test # C5 *(Steps)*	Batch Quantity *(lbm)*	Individual Batch Concentration *(ft³/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
C5.0	0	0	0	0.04	Pretest C5	412
C5.1	3.45	0.00057	3/4	0.04	C5.1	412

5.2 Alternate Flow Tests F1, F2

Table 5-6: Test F1

Flow Test F1 on GE Stacked Disk Strainer (1/8" hole size) (Nukon, 2500 gal. Tank, 206 gpm, 23 ft² Screen)						
Test # F1 (Steps)	Batch Quantity (lb_m)	Individual Batch Concentration (ft^3/gal)	Theoretical Bed Thickness (nominal) (in)	Approach Velocity (ft/s)	Filter ID (End of Step)	Flow (gpm)
F1.0	0	0	0	0	Pretest F1	206
F1.1	0.58	0.000096	1/8	0.02	F2.1	206
F1.2	0.58	0.000096	1/4	0.02	F2.2	206
F1.3	0.58	0.000096	3/8	0.02	F2.3	206
F1.4	0.58	0.000096	1/2	0.02	F2.4	206
F1.5	0.58	0.000096	5/8	0.02	F2.5	206
F1.6	0.58	0.000096	3/4	0.02	F2.6	206

Table 5-7: Test F2

Flow Test F2 on GE Stacked Disk Strainer (1/8" hole size) (Nukon, 2500 gal. Tank, 618 gpm, 23 ft² Screen)						
Test # F2 (Steps)	Batch Quantity (lb_m)	Individual Batch Concentration (ft^3/gal)	Theoretical Bed Thickness (nominal) (in)	Approach Velocity (ft/s)	Filter ID (End of Step)	Flow (gpm)
F2.0	0	0	0	0.06	Pretest F2	618
F2.1	0.58	0.000096	1/8	0.06	F3.1	618
F2.2	0.58	0.000096	1/4	0.06	F3.2	618
F2.3	0.58	0.000096	3/8	0.06	F3.3	618
F2.4	0.58	0.000096	1/2	0.06	F3.4	618
F2.5	0.58	0.000096	5/8	0.06	F3.5	618
F2.6	0.58	0.000096	3/4	0.06	F3.6	618

5.3 Alternate Debris Tests D1, D2

Table 5-8: Test D1

Debris Tests D1 on GE Stacked Disk Strainer (1/8" hole size) – TEMP-MAT (0.000096 ft^3/gal Batch Concentration, 2500 gal. Tank, 23 ft^2 Screen, 412 gpm)						
Test # D1 *(Steps)*	Batch Quantity *(lb_m)*	Individual Batch Concentration *(ft^3/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
D1.0	0	0	0	0.04	Pretest D1	412
D1.1	0.58	0.000096	1/16	0.04	D1.1	412
D1.2	0.58	0.000096	1/8	0.04	D1.2	412
D1.3	0.58	0.000096	3/16	0.04	D1.3	412
D1.4	0.58	0.000096	1/4	0.04	D1.4	412
D1.5	0.58	0.000096	5/16	0.04	D1.5	412
D1.6	0.58	0.000096	3/8	0.04	D1.6	412
D1.7	0.58	0.000096	7/16	0.04	D1.7	412
D1.8	0.58	0.000096	1/2	0.04	D1.8	412
D1.9	0.58	0.000096	9/16	0.04	D1.9	412
D1.10	0.58	0.000096	5/8	0.04	D1.10	412
D1.11	0.58	0.000096	11/16	0.04	D1.11	412
D1.12	0.58	0.000096	3/4	0.04	D1.12	412

Table 5-9: Test D2

Debris Tests D2 on GE Stacked Disk Strainer (1/8" hole size) – ROCK WOOL (0.000096 ft^3/gal Batch Concentration, 2500 gal. Tank, 23 ft^2 Screen, 412 gpm)						
Test # D2 *(Steps)*	Batch Quantity *(lb$_m$)*	Individual Batch Concentration *(ft^3/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
D2.0	0	0	0	0.04	Pretest D2	412
D2.1	0.58	0.000096	1/16	0.04	D2.1	412
D2.2	0.58	0.000096	1/8	0.04	D2.2	412
D2.3	0.58	0.000096	3/16	0.04	D2.3	412
D2.4	0.58	0.000096	1/4	0.04	D2.4	412
D2.5	0.58	0.000096	5/16	0.04	D2.5	412
D2.6	0.58	0.000096	3/8	0.04	D2.6	412
D2.7	0.58	0.000096	7/16	0.04	D2.7	412
D2.8	0.58	0.000096	1/2	0.04	D2.8	412
D2.9	0.58	0.000096	9/16	0.04	D2.9	412
D2.10	0.58	0.000096	5/8	0.04	D2.10	412
D2.11	0.58	0.000096	11/16	0.04	D2.11	412
D2.12	0.58	0.000096	3/4	0.04	D2.12	412

5.4 Alternate Strainer Design Tests S1, S2

Table 5-10: Test S1

Strainer Design Tests S1 on GE Stacked Disk Strainer (3/32" hole size) (Nukon, 2500 gal. Tank, 412 gpm, 23 ft² Screen)						
Test # S1 *(Steps)*	Batch Quantity *(lb_m)*	Individual Batch Concentration *(ft^3/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
S1.0	0	0	0	0.04	Pretest S1	412
S1.1	0.58	0.000096	1/8	0.04	S1.1	412
S1.2	0.58	0.000096	1/4	0.04	S1.2	412
S1.3	0.58	0.000096	3/8	0.04	S1.3	412
S1.4	0.58	0.000096	1/2	0.04	S1.4	412
S1.5	0.58	0.000096	5/8	0.04	S1.5	412
S1.6	0.58	0.000096	3/4	0.04	S1.6	412

Table 5-11: Test S2

Strainer Design Tests S2 on Enercon Strainer (3/32" hole size) (Nukon, 2500 gal. Tank, 718 gpm, 40 ft² Screen)						
Test # S2 *(Steps)*	Batch Quantity *(lb_m)*	Individual Batch Concentration *(ft^3/gal)*	Theoretical Bed Thickness (nominal) *(in)*	Approach Velocity *(ft/s)*	Filter ID *(End of Step)*	Flow *(gpm)*
S2.0	0	0	0	0.04	Pretest S2	718
S2.1	0.58	0.000096	1/8	0.04	S2.1	718
S2.2	0.58	0.000096	1/4	0.04	S2.2	718
S2.3	0.58	0.000096	3/8	0.04	S2.3	718
S2.4	0.58	0.000096	1/2	0.04	S2.4	718
S2.5	0.58	0.000096	5/8	0.04	S2.5	718
S2.6	0.58	0.000096	3/4	0.04	S2.6	718

6.0 TEST EQUIPMENT AND SPECIFICATIONS

The data acquisition system is used to collect flow rate, differential pressures, turbidity, and temperature data throughout the performance of the test. This system also allows for the creation of graphs of the data as well as tables of the raw data.

Due to instrument noise and combined instrument uncertainties, the data that is displayed via NI LabVIEW™ is floating-average averaged over the previous 10 data points, with each data point recorded every 2 seconds. This averaging may lead to small discrepancies in redundant instrument readouts. In such a case, the most conservative measurement for any given instrument must be recorded in the test logs. For instance, the lowest flow rate, highest differential pressure, and highest temperature should be recorded in the test logs.

The details of the equipment used and the calibration of the following instruments in this testing are identified and controlled in the Test Program Description, ALION-PLN-LAB-2352-003, "Hydraulic Testing of Debris Program Description: Test Tank" [8] and Alion "Test Equipment Verification Procedure" [7]. The following is a summary of the equipment used in this testing:

- Scales and Balances, as needed (balances verified prior to use)
  - 0 to 610 grams range, +/- 0.02 grams
  - 0 to 220 grams range, +/- 0.0002 grams
- Pressure transmitters, as needed
  - 0 to 100 and 0 to 250 inches of water, ± 0.17% error of span
  - 0 to 300 inches of water, ± 0.25% error of span
- Flow orifice
  - 70 to 700 and 400 to 1200 gpm, ± 2.5% of measured velocity
- Thermocouples
  - 32 °F to 1652 °F range, ± 3°F; LabView verified to ±5%
- Temperature probe
  - -40 °F to 1350 °F range, ±(0.1% reading °C, ±1.8°F)
- Turbidity probe
  - 0 to 2000 NTU, for information only
- NI LabVIEW™ data acquisition system
  - Real-time analog data acquisition system, allowing continuous display of test parameter values and trends. Data is sampled every two seconds, and averaged over the previous 10 data points. Test data is recorded for each instrument in a simple spreadsheet for later analysis.
- 5-micron filter bags, 90% nominal capture.

7.0 TEST ACCEPTANCE CRITERIA

In accordance with the test objective, the acceptance criterion for this testing is to conduct the fiber bypass test in accordance with the Test Matrix and applicable test procedures outlined in this document and to successfully collect and record data.

Fiber that bypasses the test strainer will be collected continuously throughout the test, and physically examined and quantified at the conclusion of testing. The tests will be monitored by lab personnel and measurements will be recorded manually throughout the tests.

7.1 Debris Load Limit Criteria

The result from pool concentration test C2 will be used to establish the debris load limit beyond which additional bypass fiber is not observed. This will be determined by collecting filter bags after 5 pool turnovers have occurred for each individual fiber batch addition. Bypass will be considered to be prevented by the formation of the fiber on the strainer when the difference between a fully dried test filter bag mass is equal to the fully dried pretest (control) filter bag within instrumentation tolerance. It is postulated that bypass will be prevented at a debris load that yields complete screen coverage with a minimum bed thickness equivalent to the perforated hole size (1/16"—1/8"). However, the results from this evaluation cannot be determined until after the test activities are complete and the filter bags have been thoroughly dried. Therefore, fiber additions shall be performed beyond the expected limiting quantity. To ensure a sufficient fiber bed has formed that will preclude additional bypass, fiber shall be added to test C2 that yields a theoretical bed thickness of ¾". Subsequent tests performed to evaluate the range of pool concentrations will only utilize debris loads up to the determined bypass load limit. Note that pool turnover times are based on water level and flow rate, and must be calculated separately for each subtest.

7.2 Step Completion Criteria

The tests identified in the test matrix require the addition of individual fiber batches into the test tank. After each batch addition, 5 pool turnovers shall be allowed to ensure that all added fiber flows through the strainer.

At the completion of each fiber addition step in the test matrix, debris observed to have settled shall be agitated manually with the intent to ensure that debris reaches the strainer module and that no significant quantities of debris are allowed to settle elsewhere in the Test Tank. However, manual agitation shall continue only until further manual stirring has no noticeable effect on the system head loss or the amount of settled debris. Supplemental agitation shall be conducted carefully to avoid disturbing the debris bed on the strainer module.

7.3 Equivalent Results Criteria

The test series presented in the test matrix is designed to identify which ECCS strainer operating parameters impact the quantity of bypass fiber. This will be accomplished by performing multiple tests that vary one parameter while holding others constant, and then comparing the results. Some variation in test results is expected, even between completely identical tests. Therefore, a tolerance for comparison of test results within the test series must be established. A comparison of bypass quantities between tests shall be considered equivalent when the measured quantities are within 10.0% of each other. However, this criterion shall be evaluated upon obtaining actual bypass quantities to ensure the tolerance is appropriate for the mass collected. Any recommended deviation from this criterion shall be discussed with the BWROG.

7.4 Test Termination Criteria

The following cases require that the test be immediately terminated and the pump secured OFF to avoid equipment damage or personal injury:

a) The head loss across the debris bed shall not exceed 16 ft-water. If reached, the flow rate will be reduced as specified in the test procedure. If reducing the flow rate as specified fails to maintain the head loss below 16 ft-water, the test must be terminated and the pump must be secured OFF.

b) Any catastrophic system failure, such as loss of power or equipment malfunction (for which no spare is available), will require test termination. In this event, the test coordinator shall determine the necessity for re-test.

8.0 TEST DOCUMENTATION AND RECORDS

The test specific procedure and Test Matrix provide the instructions for performing the required test steps, and the associated signatures provide documentation for the performance and witnessing of critical steps. This test procedure also provides for a test log, which is used to document significant points during the performance of the test.

The Test Equipment Verification Procedure [7] provides the means to verify the calibration and setup of each instrument before testing to ensure error-free data acquisition. Furthermore, the procedure is conducted near the end of testing to check for instrument failure or inaccuracies produced during testing.

The test logs are used to track the overall progression of testing, and not used as safety-related measurements. The data file recorded by the data acquisition system is used for all stabilization calculations, post-test analysis, trending, and application. The Fiber Bypass Report will further clarify how the test data can be utilized.

9.0 DEBRIS HANDLING REQUIREMENTS

This test plan identifies a test matrix using fiberglass insulation. All appropriate MSDSs shall be followed, and the following be used when handling (preparing, mixing, and adding into the test tank) the materials:

- Safety glasses with side shields or goggles
- Cloth or Tyvek laboratory coat
- Dust mask with a N95 rating like 3M Model 8210
- Latex, nitrile or neoprene gloves (leak check gloves before use)
- Long-sleeved shirt and long pants (recommended)
- Fire extinguisher with water, foam, carbon dioxide or dry powder

None of the testing debris is directly harmful under normal testing use (submerged in the test tank water); therefore, the above personnel safety equipment is unnecessary between debris additions or preparation.

10.0 QUALITY ASSURANCE REQUIREMENTS

The test program is developed, implemented, and maintained in accordance with the Alion Science and Technology Innovative Technology Solutions Operation (ITSO) Quality Assurance (QA) Program for nuclear safety-related services. Those processes that affect the quality of the output are identified and controlled by project specific procedures.

The goal of the test program is to develop fiber bypass data that may be used to support safety related analyses; therefore, the data shall be obtained and developed in accordance with the Alion ITSO 10CFR50 Appendix B QA Program. Materials, parts, and components used by the testing program do not perform safety related functions and are not designated for installation and use in nuclear facilities. The data developed from the test program, however, will be used to validate the performance and/or form the basis for design of components installed in a nuclear facility. Measuring and test equipment is calibrated in accordance with the ITSO QA Program.

It should be noted that the performance or critical characteristics of the test apparatus and equipment are not the same as that required for a nuclear safety-related system (i.e. not withstand a design basis accident); however, to ensure a quality output, the input and process will be controlled in a quality manner. Those processes that affect quality will be identified and controlled by project-specific procedures. Those processes that affect quality are: preparation of test specimens, measurement and test equipment (procurement, calibration, and data collection), and test operation.

The fit, form, and function of materials, parts, and components used for testing and analysis by Alion are controlled by specification to ensure the required design characteristics are established to duplicate and/or model safety-related nuclear components. Certificates of conformance and compliance may be used to document specification or design compliance for materials, parts, or components.

Debris materials tested are supplied commercially from original equipment manufacturers.

11.0 REFERENCES

Current revisions of all Alion procedures shall be used.

1. BWROG-ECCS-TA13-002, BWROG ECCS Strainer Bypass Testing Technical Specification, Revision 0.

2. Meeting Summary, November 27, 2007, with Boiling Water Reactor Owners' Group to Discuss the Treatment of Generic Safety Issue 191 Technical Issues Applied to Boiling Water Reactor [ML073320404].

3. Letter from Grobe, John to Anderson, Richard, "Subject: Potential Issues related to Emergency Core Cooling Systems Strainer Performance at Boiling Water Reactors," April 10, 2008 [ML080500540].

4. ALION-SPP-LAB-2352-22 – Debris Preparation Procedure.

5. ALION-SPP-LAB-2352-21 – Test Lab Safety Procedure.

6. ALION-SPP-LAB-2352-44 – Test Tank Fill Procedure.

7. ALION-SPP-LAB-2352-13 – Test Equipment Verification Procedure.

8. ALION-PLN-LAB-2352-003 – Hydraulic Testing of Debris Program Description: Test Tank

9. ALION-SPP-LAB-2352-45 – Test Tank Draining and Cleaning Procedure

10. NEI 04-07 Volume 1, Pressurized Water Reactor Sump Performance Evaluation Methodology

11. Email from Aida Muntion Villate to Brad Tyers, Bypass Specification Data from Nuclenor, dated June 15, 2011.

APPENDIX 1 – TEST MATRIX FORMULATION METHODOLOGY

Testing must provide data that can be compiled to evaluate bypass fiber quantities that could occur over the range of BWROG plant designs and conditions. Since operating parameters vary across the fleet, attributes that impact bypass quantity will be determined. The following approach will be implemented to determine which operating attributes must be considered to determine fiber bypass:

1) The ECCS operating attributes (bypass attributes) that have an impact on the bypass fiber quantity must be isolated to allow comparison with multiple plant designs. This will be demonstrated by measuring the bypass debris that results from changing the following controlled variables in individual tests while maintaining other conditions constant:

   a) Debris concentration in the test medium
   b) Debris load
   c) Debris Type
   d) Strainer Design
   e) Flow

2) Tests will then be structured to determine the bypass debris quantity that results from varying the attributes determined to have an impact throughout the range of BWROG plant conditions. The data will be complied to allow each plant to determine the bypass quantity based on their individual operating conditions such as ECCS flow and suppression pool fiber concentration. The data will be complied in a manner that allows for determination of bypass quantity that is associated with a specific time during ECCS operation.

Inherent to the approach described below is the assumption that the destroyed fibrous debris will be homogeneously dispersed throughout the suppression pool in order to determine pool concentration. The dispersal of the destroyed fiber is postulated to occur during the pool fill phase of the LOCA, prior to RHR or CS pump initiation.

To collect the desired data, one strainer design will initially be selected to serve as a test constant while debris and operating conditions are varied in individual tests. Since this will require a number of tests for each varied attribute, the GE stacked disk strainer will be selected as the base strainer due to availability and ease of installation. Test sequences are then performed that vary initial debris concentrations in the test pool, the quantity of debris added to the test, the flow through the strainer and the type of fiber. From this initial test sequence the strainer bypass load limit will also be determined. This is the amount of fiber accumulated on the screen that prevents additional bypass.

The ranges of controlled parameters used in the tests will be based on the limiting conditions reported by the BWROG.

The data will be examined to identify the parameters that impact the bypass quantity. The next series of tests will be performed using an alternate strainer design. A representative set of test conditions from the base strainer test series will be performed in the same manner for the alternate strainer. The results between the test series will be compared to determine if the physical strainer design has any additional impact on the bypass quantity.

The final results will be compiled to quantify the amount of bypass fiber that will occur with respect to the mass of fiber that reaches the strainer. Using this relationship in conjunction with plant specific ECCS operating conditions will allow each BWROG plant to determine the amount of fiber expected to bypass the ECCS strainers at a given point in time. This will be accomplished by deriving the volume of fiber that reaches the strainer from the design values of pool concentration (ft^3/gal) and flow (gal/min). The resulting value of fiber flow to the strainer (ft^3/min) can be associated with any specific time interval to calculate the amount of fiber that will interact with the strainer. This data point can then be compared to the corresponding test data for bypass quantity vs. fiber quantity transported to the strainer to determine a plant specific value.

The plants' debris loads and ECCS operating parameters are given in Reference 1 [1]. The following table reflects the plant pool concentration ranges for the various strainer designs, the desired test article surface area and the resulting bed thicknesses:

		Low Concentrations			High Concentration		
Test Strainer	Screen Area	Low Concentration (LC)	LC Test Tank Fiber Quantity	Bed Thickness	High Concentration (HC)	HC Test Tank Fiber Quantity	Bed Thickness
	(ft^2)	*(ft^3/gal)*	*(ft^3)*	*(in.)*	*(ft^3/gal)*	*(ft^3)*	*(in.)*
ABB	40	0.00022	0.55	0.165	0.0023	5.75	1.73
Enercon/Transco	40	0.00035	0.875	0.262	0.0011	2.75	0.825
GE	23	0.000013	0.0325	0.017	0.0018	4.5	2.3
PCI	40	0.00007	0.175	0.053	0.0015	3.75	1.125
CCI[1]	40	0.0002	0.6	0.18	*n/a*	*n/a*	*n/a*

[1] The pool concentration of 0.0002 ft3/gal is representative of both the Nuclenor and Cofrentes plants.

APPENDIX 2 – SCALING RATIOS

The initial test series (C1-C5) will vary the concentration of fiber in the test tank based on the volume ratios of fiber (ft^3) in the plant suppression pools to the associated suppression pool volume (gal). Since the test tank in the Alion laboratory operates with a nominal volume of 2500 gallons, this value will be used to determine the individual batch quantities to be added to the test tank. As the test batches will be measured by mass, the required volume will be converted based on the as fabricated density of the debris utilized:

$$Test\ Batch\ Quantity[lb] = \frac{Vplant\ fiber[ft^3]}{V\ plant\ pool[gal]} \times 2500\ gal \times \rho debris[\frac{lb}{ft^3}]$$

To allow comparison between tests, the theoretical bed thickness on the strainer will be determined based upon the quantity of fiber added to the tank. Although the actual bed thickness will be reduced by the amount of fiber that bypasses the strainer, this parameter is useful for comparing results between tests based on the amount of fiber added. The bed thickness is defined as the volume of debris at the as-fabricated density divided by the strainer surface area:

$$BedThickness[in.] = \frac{V_{debris}[ft^3]}{A_{strainer}[ft^2]} \times 12\left[\frac{in.}{ft}\right]$$

The plant flow rates will be scaled to the prototypes based on equivalent theoretical approach velocities. Approach velocity is defined as the volumetric flow rate divided by the screen area:

$$ApproachVelocity[ft/s] = \frac{Q[gpm]}{A_{strainer}[ft^2]} \div 448.8\left[\frac{gpm}{ft^3/s}\right]$$

APPENDIX 3 – FIBER SIZE CLASSIFICATIONS

APPENDIX 4
Plant Survey Data

Plant	System	Strainer Vender	Perf Hole Size (in.)	Debris Type	Debris (ft^3)	Pool Volume (gal)	Debris Conc. (ft^3/gal)	Flow (gpm)	Strainer Area (ft^2)	MAX Approach Velocity (ft/s)	Bed Thickness (in.)
Plant 1	BWR/4-Mark II	ABB	1/16	Nukon	197	914,000	0.0002155	RHR 11,000 CS 3950	RHR 906.4 CS 190.8	RHR 0.0271 CS 0.05	RHR 2.61 CS 12.4
Plant 2	BWR/4-Mark II	ABB	1/16	Nukon	377	914,000	0.0004125	RHR 11,000 CS 3950	RHR 906.4 CS 190.82	RHR 0.0271 CS 0.05	RHR 4.99 CS 23.8
Plant 3	BWR-Mark I	ABB CE	1/8	Nukon, Fiberglass	1462	919,356	0.00159	RHR 10,900 CS 4500	RHR 620.16 CS 244.8	RHR 0.0392 CS 0.041	RHR 28.3 CS 71.7
Plant 4	BWR-Mark I	ABB CE	1/8	Nukon, Fiberglass	2070	919,356	0.00225	RHR 10,900 CS 4500	RHR 620.16 CS 244.8	RHR 0.0392 CS 0.041	RHR 40.50 CS 101.5
Plant 5	BWR/6-Mark III	Enercon	3/32	Nukon	8	1,091,606	0.0000073	RHR 6,060 CS 6450	RHR 2407 CS 2407	RHR 0.0056 CS 0.0059	RHR 0.04 CS 0.04
Plant 6	BWR/6-Mark III	Enercon	3/32	Nukon	906	852,435	0.0010628	RHR 17,040 CS 7800	RHR 2165.4	0.0175	5.02
Plant 7	BWR/6-Mark III	Enercon/ Transco	3/32	Thermal Wrap	350	990,462	0.0003534	RHR 7,450 CS 7115	RHR 2418 CS 2418	RHR 0.0069 CS 0.0066	RHR 1.74 CS 1.74
Plant 8	BWR/4-Mark I	GE	1/8	asbestos cloth, rockwool, fiberglass, Cal Sil	11.76	919,822	0.0000128	RHR 10,500 CS 4125	RHR 298 CS 596	RHR 0.0786 CS 0.015	RHR 0.47 CS 0.24
Plant 9	BWR/4-Mark I	GE	1/8	asbestos cloth, rockwool, fiberglass, Cal Sil	11.76	919,822	0.0000128	RHR 10,500 CS 4125	RHR 298 CS 596	RHR 0.0786 CS 0.015	RHR 0.47 CS 0.24
Plant 10	BWR/4-Mark I	GE	1/8	asbestos cloth, rockwool, fiberglass, Cal Sil	11.76	919,822	0.0000128	RHR 10,500 CS 4125	RHR 298 CS 596	RHR 0.0786 CS 0.015	RHR 0.47 CS 0.24
Plant 11	BWR/4-Mark I	GE	1/8	Thermal Wrap	23	655,668	0.0000351	RHR 9240 CS 6525	RHR 424 CS 250	RHR 0.0486 CS 0.058	RHR 0.65 CS 1.10
Plant 12	BWR/4-Mark I	GE	1/8	Nukon	150	440,603	0.0003404	RHR 6,500 CS 4500	RHR 387.51 CS 290.58	RHR 0.0374 CS 0.034	RHR 4.65 CS 6.19
Plant 13	BWR/4-Mark I	GE	1/8	Nukon	25	905,678	0.0000276	RHR 15,300 CS 7900	RHR 387 CS 387	RHR 0.0882 CS 0.045	RHR 0.78 CS 0.78
Plant 14	BWR/6-Mark III	GE	3/32	fiberglass, Nukon	1800	1,010,869	0.0017806	RHR 6060 CS 6400	RHR 606 CS 606	RHR 0.0223 CS 0.0235	RHR 35.64 CS 35.64
Plant 15	BWR/4-Mark I	PCI	3/32	Tempmat, Nukon, Cal-Sil	274.9	646,691	0.00042509	10,500	256.76	0.091	12.85
Plant 16	BWR/4-Mark I	PCI	3/32	Tempmat, Nukon, Cal-Sil	296	646,691	0.00045771	3350	122.46	0.061	29.01
Plant 17	BWR/4-Mark I	PCI	3/32	Tempmat, Nukon, Cal-Sil	274.9	646,691	0.00042509	10,500	256.76	0.091	12.85
Plant 18	BWR/4-Mark I	PCI	3/32	Tempmat, Nukon, Cal-Sil	296	646,691	0.00045771	3350	122.46	0.061	29.01

Plant	System	Strainer Vender	Perf Hole Size (in.)	Debris Type	Debris (ft^3)	Pool Volume (gal)	Debris Conc. (ft^3/gal)	Flow (gpm)	Strainer Area (ft^2)	MAX Approach Velocity (ft/s)	Bed Thickness (in.)
Plant 19	BWR/5-Mark II	PCI	3/32	Tempmat	58	839,295	0.0000691	8000	197	0.0906	3.53
Plant 20	BWR/4-Mark I	PCI	3/32	Nukon, Tempmat, fiberglass, Thermal Wrap	794	796,241	0.000997	RHR 10,500 CS 6800	RHR 1128 CS 336	RHR 0.0208 CS 0.045	RHR 8.45 CS 28.36
Plant 21	BWR/4-Mark I	PCI	1/8	Nukon	425	882,700	0.0004815	RHR 12,500 CS 8400	RHR 667.5 CS 269.2	RHR 0.042 CS 0.070	RHR 7.64 CS 18.94
Plant 22	BWR/3-Mark I	PCI	1/8	Nukon	700	442,995	0.0015802	RHR 4347 CS 4285	RHR 1225 CS 1225	RHR 0..0079 CS 0.0078	RHR 6.86 CS 6.86
Plant 23	BWR/3-Mark I	PCI	1/8	Nukon	263.6	628,000	0.0004197	RHR 5600 CS 4950	RHR 670 CS 670	RHR 0.0186 CS 0.0164	RHR 4.72 CS 4.72
Plant 24	BWR/3-Mark I	PCI	1/8	Nukon	73.16	834,078	0.0000877	RHR 5137 CS 6222	207	0.067	4.24
Plant 25	BWR/3-Mark I	PCI	1/8	Nukon	73.16	834,078	0.0000877	RHR 5137 CS 6222	207	0.067	4.24
Plant 26	BWR/4-Mark I	PCI	1/8	Nukon, Fibermat	857	508,674	0.0016848	RHR 8990 CS 4830	RHR 810 CS 434	RHR 0.0248 CS 0.0248	RHR 12.70 CS 23.70
Plant 27	BWR/3-Mark I	PCI Sure-Flow	1/8	Nukon	18.4	869,985	0.0000211	RHR 6,000 CS 6200	RHR 118 CS 118	RHR 0.1134 CS 0.1170	RHR 1.87 CS 1.87
Plant 28	BWR/3-Mark I	PCI Sure-Flow	1/8	Nukon	18.4	869,985	0.0000211	RHR 6,000 CS 6200	RHR 118 CS 118	RHR 0.1134 CS 0.1170	RHR 1.87 CS 1.87
Plant 29	BWR/2-Mark I	PCI	1/8	Tempmat, Nukon, Lead Blanket Covers	58.5	598,440	0.00009775	3725	240	0.0346	5.74
No Fibers											
Plant 30	BWR/4-Mark I	GE	1/8								
Plant 31	BWR/4-Mark I	GE	1/8								
Plant 32	BWR/5-Mark II	PCI	3/32	n/a	0	963,350	0.0000000	8100	100	0.1806	0.00
Plant 33	BWR/5-Mark II	PCI	3/32	n/a	0	963,350	0.0000000	8100	100	0.1806	0.00
Plant 34	GE-BWR/4; Wet, Mark II	GE	1/8	Nukon	1.9	915,627	0.0000021	13,800	204	0.1509	0.112
Plant 35	GE-BWR/4; Wet, Mark II	GE	1/8	Nukon	1.6	915,627	0.0000017	13,800	204	0.1509	0.094
Atypicals											
Plant 36	BWR/2-Mark I	GE	1/8	Nukon	242	613,313	0.0003946	4400			
Plant 37	BWR/6-Mark III	CCI	0.082	Nukon	200	850,909	0.0002350	5940	400	0.0331	6.0
Plant 38	BWR/3-Mark I	CCI	0.082	Nukon, Kwool	88.75	447,474	0.0001983	13,525	689.68	0.171	2.1994
Plant 39	BWR/5-Mark II	GE	3/32	Tempmat, Min-K	6.3	1,122,078	0.00000561	8200	49.41	0.3701	1.53