APR1400 IRWST ECCS Sump Strainer Prototype Hydraulic Qualification Test Plan

Non Proprietary

JULY 2013

This test plan for IRWST ECCS sump strainer head loss, bypass, and hydraulic effect was prepared to provide the test condition and test method which will be performed at the APR1400 specific conditions.

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All	All	0	7/15/2013	Initial Draft Issue for Comment

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Acronyms and Definitions

CSS	Containment Spray System
ECCS	Emergency Core Cooling System
GSI	Generic Safety Issue
HELB	High Energy Line Break
IRWST	In-containment Refueling Water Storage Tank
LDFG	Low Density Fiberglass
LOCA	Loss of Coolant Accident
M&TE	Measuring and Test Equipment
NEI	Nuclear Energy Institute
NPP	Nuclear Power Plant
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
PWR	Pressurized Water Reactor
RHR	Residual Heat Removal
RMI	Reflective Metallic Insulation
SER	Safety Evaluation Report
SIS	Safety Injection System
TPI	Transco Products Incorporated

1 BACKGROUND

The APR1400 has four (4) ECCS/CS trains with an independent 1,200 ft^2 strainer for each train for a total of 4,800 ft^2 [1]. The design requires a minimum of three trains in operation (3,600 ft^2) assuming one train with a single failure. The strainers prevent debris from being ingested into the Safety Injection system (SIS) and Containment Spray system (CSS) in the event of a loss-of-coolant-accident (LOCA) and are located within the In-containment Refueling Water Storage Tank (IRWST).

The design and evaluation methods for the strainer performance are in accordance with the latest revision of Regulatory Guide 1.82 [2]. If a LOCA inside the reactor building were to occur, it could generate debris that, if transported to and deposited on the recirculation sump screens, could challenge the safety function of the recirculation sumps. Specifically, debris that could accumulate on the sump screens would increase head loss across the resulting debris bed and sump screen. This head loss might be sufficiently large such that it may exceed the net positive suction (NPSH) margin of the SIS and CSS pumps that draw from the sump.

The purpose of this test is to develop head loss data to validate IRWST sump strainer performance using a conservative assumption that all debris is 100% transported to a single sump strainer. Furthermore, the strainer is designed (sized) such that all of this debris produces a nominal debris bed thickness of no more than 1/8” if equally distributed on the strainer surface area. The intent is define the APR1400 as a no/low-fiber or clean plant with respect to the resolution of Generic Safety Issue No. 191. Should this test program find the head losses to be unacceptable, the mass of latent fiber may be reduced or the strainer surface area can be increased.

The staff recently approved “clean-plant” criteria [5] that provide guidance to resolve the strainer and in-vessel issues.

Strainer Head Loss

The following acceptance criteria should be met by any plant desiring to use the “clean-plant” methodology to demonstrate acceptable strainer head loss:

1) Validate that all fibrous debris installed in any ZOI within the scope of GL 2004-02 plus latent fibrous debris results in a theoretical maximum debris bed thickness of 1/16 inch covering the area of all ECCS/CSS strainers installed in the plant and assuming 2.4 lb/ft^3 as the material density and 100% transport of all material.
2) Remove or validate that no problematic insulation types are installed in any ZOI within the scope of GL 2004-02. A plant may have problematic insulation types installed if a staff accepted head loss test demonstrates adequate strainer performance.
3) Maintain a cleanliness program that ensures that latent fibrous debris within containment is maintained within the limits described in (1) above.
4) Plants with strainers installed in pits below the containment floor elevation must demonstrate that paint chips will not adversely affect the strainer head loss. The staff will review the evaluation of the effects of coating chips on strainer performance.
5) Plants must satisfy other criteria relevant to strainers addressed by the staff safety evaluation on the NEI Guidance Report, NEI 04-02. These criteria include, but are not limited to: NPSH, vortexing, upstream effects, and structural integrity.
6) For establishing the plant licensing basis, plants that maintain the source term per (1),
7) (2), and (3) above may use the clean-strainer head loss plus a debris head loss based on representative testing for the total strainer head loss. Based on observations of conservative head loss tests conducted with approximately 1/16 inch theoretical bed thickness and no problematic debris, the staff considers two feet of debris head loss to be an acceptable assumption in the absence of representative testing. This value is representative of the higher head loss values obtained during head loss testing with equal or greater fibrous debris loads conducted under conservative conditions.

In lieu of representative testing in number (7) above, plant specific testing may be performed to validate the head loss associated with the thin-bed. The expectation here is that head losses are either negligible or minimal with debris beds less than 1/8". The purpose of this test program is to validate the head losses associated with the APR1400 screen design and plant specific loading.

2 TEST APPROACH

This head loss test plan is designed in accordance with the head loss testing guidance provided in *NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing* dated March 2008 [3]. This staff guidance provides acceptable methods to perform prototype strainer head loss testing.

2.1 Test Objective

The objective of the tests is to develop experimental head loss data associated with the debris accumulated on the sump strainer from the most limiting high-energy line break in containment. Flow sweeps will be conducted to obtain additional head loss data as a function of flow rate (i.e., approach velocity) to adjust the head loss over the range of fluid temperatures required for sump operation.

The tests will collect and record differential pressure across the strainer, fluid temperature, and pump flow rate for the debris mixtures identified in the test matrix. The proposed test in this test plan are designed to demonstrate that the head loss associated with the strainer configuration is acceptable for the design debris loading. Acceptance in this definition is within available ECCS/CS pump NPSH margin. This evaluation will take place outside this test report. A data report will be developed presenting the results of the testing associated with this test plan.

2.2 Test Description

A test matrix is designed to validate the performance of the sump strainer for varying debris loads from a spectrum of break locations identified in the debris generation and transport calculation [1]. For plants with the potential to generate relatively large quantities of fibrous debris, the test matrix should provide confidence that the peak head loss has been conservatively or prototypically determined. The approach is to cover the thin-bed and fully loaded debris bed case either in a single test or multiple tests as accepted by the NRC in their Supplemental Guidance [3].

The APR1400 utilizes reflective metallic insulation (RMI) as the primary insulation system in containment and therefore has very little fibrous debris that reaches the IRWST sump strainer. In fact, the only fiber component resulting from the spectrum of break locations is latent fibrous debris. The quantity of latent debris at this time (since the plant is not yet built) is an assumption. KHNP has selected 100 lbs of latent debris with 92.5%/7.5% split of particulate and fibrous constituents. However, for conservatism, the strainer area has been designed based on 200 lbs of latent debris with the NRC-approved 85/15 split of particulate and fibrous. The IRWST sump strainer in the APR1400 is designed to meet the NRC defined "clean plant criteria" which designs screens to have a minimum amount of fiber on the screen to produce little or no head loss.

A prototype section of the strainer will be installed in a test tank and loop with sufficient water volume to allow circulation of debris around the prototype. The recirculation flow through the test loop and strainer is established based on the plant strainer and flow rate.

The test will begin with a clean strainer flow sweep with no debris in the tank. This flow sweep will measure the head loss created by a clean strainer at each of the flow rates in the Test Matrix. These head loss values will be compared to the analytical values developed in the clean strainer head loss calculation. At the end of this flow sweep, the flow will be adjusted to the target test flow rate.

Given that the maximum amount of debris for the APR1400 IRWST strainer only produces a bed thickness of approximately 1/8", only a single thin-bed test will be performed. The debris test will begin by first adding in the full mass of particulate and then adding the scaled masses of fiber that correspond to 7.5 lbs and 30 lbs of fiber on a single 1200 ft^2 plant strainer (2 batches will be added), which will produce a 1/8" debris bed. After the fiber loads have been introduced and debris head loss stabilized, chemical precipitate loads will be introduced into the tank. Flow sweeps are performed at the stabilized head loss before and after the chemical precipitates are added and head loss stabilization has been achieved. Once stabilization has been achieved and flow sweeps performed, the test is terminated and complete.

2.3 Test Acceptance

The testing is designed to obtain steady-state debris head loss data as a function of flow rate and temperature for the prototype strainer assembly. Given the nature of the chemical precipitates, it is not possible to predict the head loss associated with these materials with any certainty. However, it is expected that with this small quantity of fiber debris, there will be very little head loss associated with the fiber, particulate and chemical effects.

3 TEST ARTICLE

3.1 IRWST Sump Strainer Design

The IRWST sump strainer (Figure 3-1) will fit over the existing sump pits. There are four (4) IRWST sump strainers, each with a minimum of 1,200 ft^2 for a total of 4,800 ft^2. To be conservative, the entire debris load will be applied to a 1,200 ft^2 single strainer. The test prototype will represent a single strainer during testing; therefore, the test parameters must be scaled to this value.

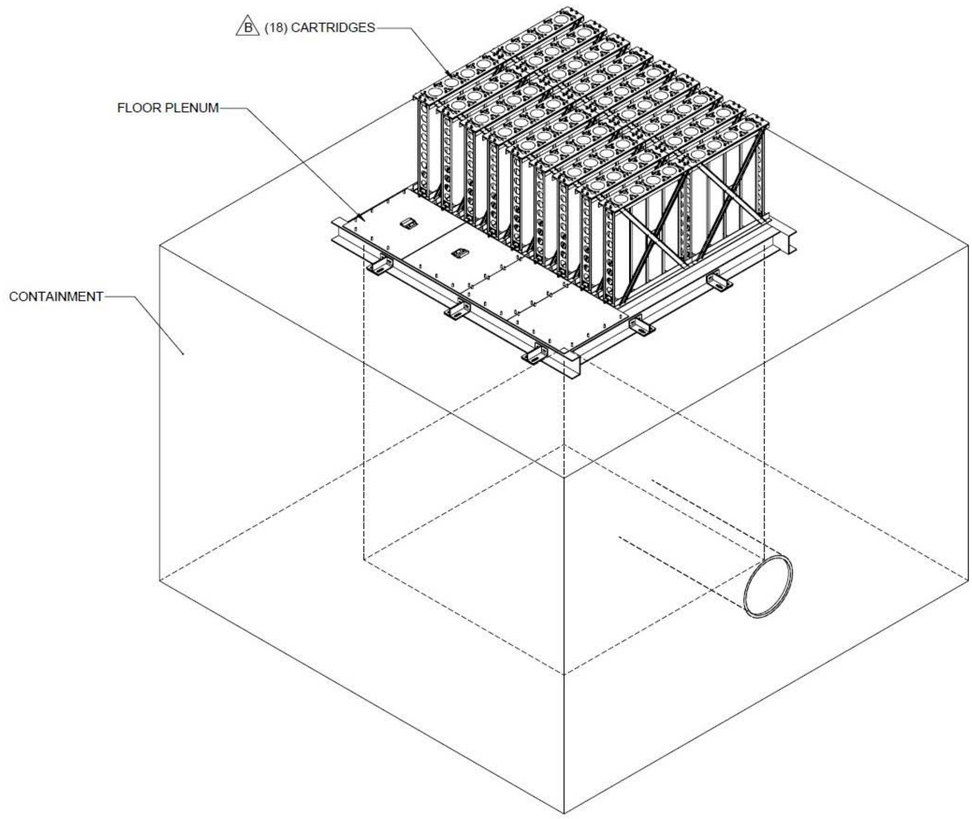

Figure 3-1: Plant Recirculation Sump Strainer

The APR1400 utilizes RMI as the primary insulation system and does not use fibrous or other problematic materials inside containment, the only source of fibrous insulation is latent debris. Therefore the types and quantities of debris are limited to latent fiber and particulate, coatings and chemical effects.

The strainer is designed based on the following conditions [1]:

1) Flow Condition
   a) Flow rate (gpm)..6,660
   b) Fluid temperature (°F) 140- 230
2) Debris Quantities
   a) Epoxy paint (ft^3)..0 – 3.1
   b) Latent fiber (lbs) 30
   c) Latent particulate (lbs) 170

d) Chemical Effects

i) Calcium Phosphate (kg) 1.0

ii) Sodium Aluminum Silicate (kg) 8.5

iii) Aluminum Oxy-hydroxide (kg) 179.5

3.2 Test Prototype Strainer

A full-scale section of the strainer prototype will be tested in the tank. This assures a 1:1 scaling ratio for test parameters, e.g. flow rate, tube diameters, and perforated plate hole size which is 3/32” [8]. The debris quantities for the prototype tests shall be in proportion to the full-scale screen size, and the flow rate through the prototype will be proportional to the full-scale strainer. The prototype strainer design is shown in Figure 3-2. The design uses cartridge assemblies to increase the surface area to any given allowable surface area. For this testing, three cartridges of four tubes each will be used. The surface area of this configuration is 75.1 ft^2. The tubes are attached to a plenum that allows a flow path from each tube to the pump suction pipe. See Figures 3-3 and 3-4. All materials of the strainer and plenum are stainless steel.

Figure 3-2: Strainer Prototype

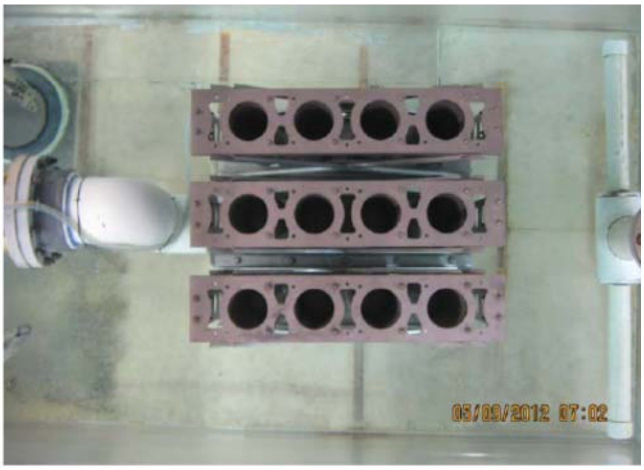

Figure 3-3: Strainer Prototype in Tank, Top View

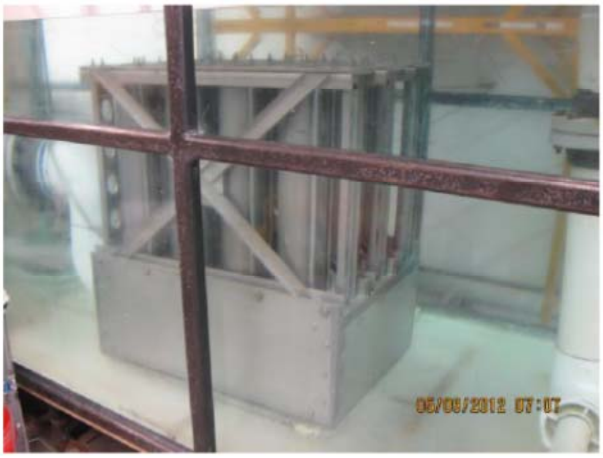

Figure 3-4: Strainer Prototype in Tank

4 TEST FACILITY

The test facility to be used will have performed strainer testing for US PWRs in the United States. There are several acceptable test facilities in the US with GSI-191 experience that have been visited/audited by the USNRC. This will assure that the protocols (debris prep, etc.) used by the facility for testing meet the USNRC expectations. The facility will contain a 2500-gallon or greater tank capable of holding the strainer with adequate room around the test prototype and the capability to achieve the target flow rate. A schematic of an example facility is shown in Figure 4-1.

The filter cartridges must be attached and sealed against the flow plenum. A sparger system should 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. In addition to the sparger, mechanical mixers may be required to keep the debris from settling.

The data acquisition program must be programmed to match the test parameters, such as screen area and correct orifice plate conversion. English units will be displayed and recorded in the test logs and data files.

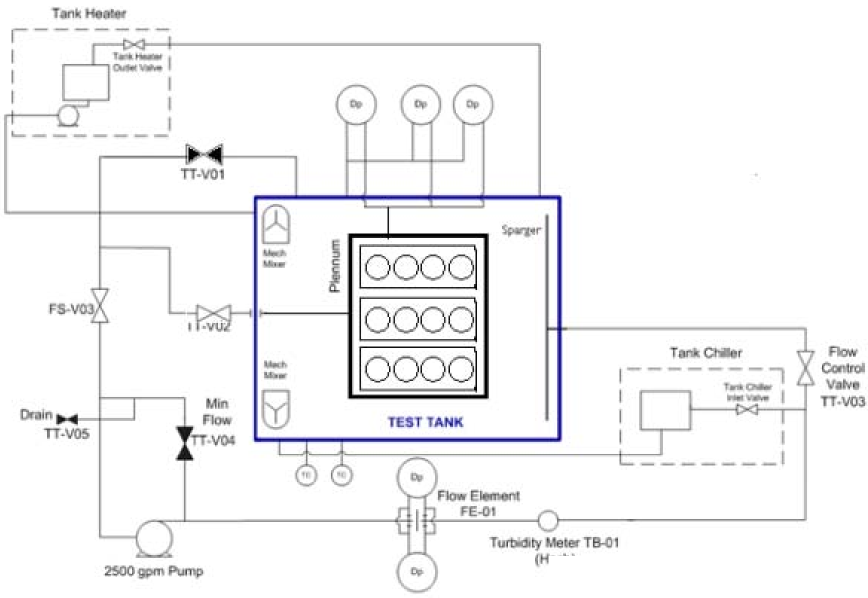

Figure 4-1: Example Tank Piping and Instrumentation Diagram

4.1 Test Equipment

The instrumentation available for use must conform to the following specifications and be within the approved calibration date.

Table 4-1: Required M&TE

Instrument	Range	Accuracy
Pressure transmitter	0 – 100 in-water 0 – 300 in-water	± 0.25% of span ± 0.25% of span
Flow meter	90 – 900 gpm	± 2.5% of reading
Thermocouple	32˚F to 212˚F	± 1% of reading
Benchtop chemistry equipment	As needed to produce WCAP-16530-NP chemical precipitates	*Various as required by test control*

Data Acquisition system, verified prior to testing and after testing

- Real-time analog data acquisition system, allowing continuous display of test parameter values and trends. Data is sampled at least 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.
- The data acquisition system is used to collect time, flow rate, differential pressure, and temperature data throughout the performance of the tests. This system also allows for the creation of graphs of the data as well as tables of the raw data.

5 TEST CONDITIONS

5.1 Hydraulic Conditions

5.1.1 Test Strainer Flow Rate

The maximum post-LOCA recirculation flow rate is 6600 gpm. The IRWST sump strainer is 1,200 ft^2 of screen area per train. Given the prototype strainers size of 75.1 ft^2, the prototype strainer flow rate is the plant flow rate multiplied by the ratio of the strainer areas:

$$6600\ gpm\ x\ \frac{75.1\ ft^2}{1200\ ft^2} = 413\ gpm$$

5.1.2 Water Temperature and Chemistry

The water temperature at the beginning of testing will between 80°F and 100°F. This temperature will increase during testing as the pump adds energy into the fluid, but the temperature should be limited to 100°F. A tank chiller should be utilized to limit the water temperature to 100°F. Tap water may be used as the testing fluid.

5.1.3 Water Level

The strainers must remain submerged during testing except during vortex formation studies. The required minimum submergence during head loss testing is 2'-0" (+/- ¼ inches).

5.1.4 Turbulence

Sufficient turbulence shall be added into the test tank during testing to preclude settling of debris. The turbulence must be limited, however, to avoid artificially removing debris from the strainers. The turbulence can be added via mixing motors or equivalent.

5.2 Debris Conditions

The following section describes the types and quantities of debris to be used for the testing.

5.2.1 Epoxy Coatings

Epoxy coatings are destroyed coatings within the Zone of Influence. Based on the upstream analysis, the quantity of destroyed coatings is 3.1 ft^3. NEI-04-07 [4] estimates the particle size of failed coatings to 10 µm on average with a density of 94 lbs/ft^3. A suitable and common surrogate used in US testing is silicon carbide (SiC) with a mean particle size of 10 µm and material specific gravity of 3.2 which corresponds to a density of 199.5 lb/ft^3. **The source and measured size distribution of the SiC used in testing shall be provided in the test report summary.** In determining the amount of SiC to add to the test it is important that the volume of particulates is preserved. Therefore the amount of SiC to be added to the test is:

$$m_p = \frac{75.1\ ft^2}{1200\ ft^2}\ x\ 3.1\ ft^3\ x\ 199.5 \frac{lbs}{ft^3} = 38.7\ lbs$$

5.2.2 Latent Debris

Latent debris defined as dirt and dust on surfaces inside containment and is comprised of a fibrous and particulate component. For strainer testing the quantity of latent debris is 200 lbs, with 170 lbs of particulate and 30 lbs of fiber.

The latent fiber will be represented by NUKON low density fiberglass which per NEI-04-07 has an as-fabricated density of 2.4 lbs/ft^3. **The source of the NUKON used in testing shall be provided in the test report summary.** The fiber added to the tank shall have a size characteristic of fines (Class 1-3) per Attachment B of NUREG/CR-6224 [6]. The mass of fiber to be added to the test is:

$$m_f = \frac{75.1\ ft^2}{1200\ ft^2}\ x\ 30\ lbs = 1.88\ lbs$$

This will produce a conservative debris bed thickness of nominally 1/8”.

The latent dirt and dust of the plant will be represented by a blend of silica sand made specifically for head loss testing. Dirt/Dust PWRII Mix will be the surrogate debris material for the latent dirt/dust, which is a material blend of silica sand representative of PWR latent dirt/dust for head loss testing. The size distribution of the silica sand shall be prepared to be consistent with the latent dirt/dust size distribution provided in Table 5-1. **The source and measured size distribution of the dirt/dust mix used in testing shall be provided in the test report summary.**

Table 5-1: Dirt/Dust Mix Requirements

PWR Mix 2	Sand Type Distributions Based on Product Data Sheets			Size Classification / Consolidation			
Sand Recipe Mix (lbs)	Coarse Sand 8	Medium Sand 54	Fine Sand 38	Allocation Basis (lbs)	PWR 2 Calc	NRC Target	
< 75 microns			98.50%	37.4	37.4%	37%	Fines
> 75 microns			1.50%	0.6	35.3%	35%	Medium
< 500 microns		63.77%		34.4			
> 500 microns		36.23%		19.6	27.3%	28%	Coarse
< 500 microns	3.37%			0.3			
> 500 but < 2000 microns	96.63%			7.7			
Note: Each type of sand has particles in two size ranges.				100.0	100.0%	100.0%	
The above recipe will achieve the NRC Target.			Sand Class Key	Fine	Medium	Coarse	

Similarly, the mass of latent particulate to be added to the test is:

$$m_{lp} = \frac{75.1\ ft^2}{1200\ ft^2}\ x\ 170\ lbs = 10.6\ lbs$$

5.2.3 Chemical Precipitates

Based on the design conditions presented in Section 3.1, the following chemical precipitates may be available in the IRWST sump fluid.

- Calcium Phosphate 1.0 kg
- Sodium Aluminum Silicate 8.5 kg
- Aluminum Oxy-hydroxide 179.5 kg

Given the relative proportions and since aluminum oxy-hydroxide can be conservatively used to represent the other precipitates, only AlOOH will be used in the test program. However the total chemical precipitate mass of 189 kg will be represented by AlOOH.

The chemical precipitate shall be prepared in accordance with the WCAP-16530-NP [7] (in terms of settling rates) and batched into the test tank in pre-defined quantities to collect the head loss data required by the test program. This precipitate suspension must have a calculated density of 11 g precipitate/L of water. The chemical precipitate settling shall be measured within 24 hours of the time the precipitate will be used and the 1-hour settled volume of 10 mL solution shall be 6.0 ml or greater and within 1.5 ml of the freshly prepared precipitate. Chemical precipitates being used within one week of manufacturing do not require a verification settling test. The volume of prepared AlOOH surrogate for the test are as follows:

$$V_{AlOOH} = \frac{75.1\,ft^2}{1200\,ft^2}\ x\ 189\ kg\ x\ \frac{L}{.011\,kg}\ x\ \frac{1\,gal}{3.785\,L} = 284\ gal$$

This is a significant amount of chemical precipitates. However, the it is anticipated that the test will not need this much precipitate due to the fact either 1) the debris bed will not cover the entire strainer uniformly by design and/or 2) the head loss will reach a maximum and adding more precipitate will not cause any further increase in head loss. The test protocol will make provisions for either of these cases.

Table 5-2: Debris Load Summary

	APR1400 Strainer		Test Strainer	
Strainer Surface Area	1200	ft^2	75.1	ft^2
Coatings	3.1	ft^3	38.7[1]	lbs
Latent particulate	170	lbs	10.6	lbs
Latent fiber	30	lbs	1.9	lbs
Chemical load	189	kg	284	gal

[1]mass of SiC surrogate.

6 TEST PERFORMANCE

All personnel working on the test (engineers, technicians, chemists, managers) must be trained to the applicable test procedures of the laboratory. At a minimum, this includes the Test Procedure, Lab Safety Procedure, Debris Preparation Procedures, Tank Operation Procedures including the operation of M&TE, and the laboratory Project Plan.

6.1 Test Procedures

All testing actions will be governed by an approved Test Procedure to be developed by the testing vendor. The test-specific procedure provides the instruction for performing the required test steps, and the associated signatures provide documentation for the performance and witnessing of critical steps. This test procedure shall also provide for a test log, which is used to document significant points during the performance of the test. Actions that affect the testing environment (debris additions, flow adjustments, stirring, etc.) shall be noted in the Test Log by a trained Test Engineer. Visual observations should also be noted. All documentation in the test log shall be legible.

The test vendor shall develop generic test procedures for debris preparation, fill and start-up testing including M&TE installation and verification, tank cleaning, lab safety, nonconformance/deviations, and head loss testing.

6.2 Debris Preparation

The debris batches shall be prepared according to the Test Matrix. The NUKON LDFG shall be processed using an approved laboratory procedure that prepares the insulation into fine debris. This procedure produces the required size distribution and fiber fines that are easily transportable and readily disperse in the testing medium. At a minimum, the insulation must be shredded and beaten into a thin slurry to produce the industry standard “fines” testing size distribution. Samples shall be taken and photographed to document the extent of fiber destruction. “Smalls” preparation reduces the requirement of mechanical beating. SiC and dirt/dust mix can be weighed out in dry form and do not require further preparation. Before introduction, water shall be carefully added into the buckets and mixed lightly to suspend the particulate and ease pouring. The recommended ratio is 10 lbs of particulate to 3 gallons of water.

The chemical precipitate batches must be prepared per the test matrix and an approved laboratory procedure that follows standard industry guidance on the formation of chemical debris in a separate tank. Once settling criteria are met, the precipitate does not need further preparation and can be slowly poured or pumped into the tank per the Test Matrix.

6.3 Test Operation

Vortexing During testing, visual observations are required to ensure that no significant vortices form. Vortex and/or swirl up to and including a Type 4 are considered acceptable. A significant vortex is defined as a Type 5 or a Type 6 vortex. Observations and photographs will also be recorded of any debris settling and abnormal loading of the prototype strainers. A vortex suppressor (floor grating or equivalent) may be installed for Type 5 or 6 vortices. TPI will be notified in the event of Type 5 or 6 vortices and the installation of a vortex suppressor.

Water Level Water level will be recorded during testing and increase with each debris addition. If the test tank becomes nearly full, test tank water may be removed to mix with the next debris addition, and re-introduced into the test tank. This will prevent tank overflow with subsequent debris additions. Furthermore, tank volume must be left over for the additions of the chemical precipitates, which cannot be mixed with the test tank water prior to addition.

Flow Rate The flow rate of the system must be maintained at ±10 gpm of the prescribed value. If the flow drifts beyond this range, a note must be logged, and the flow rate must be adjusted.

Debris Add All debris will be added directly over a high-turbulence area. These areas will have maximum relative turbulence and will allow for debris reaching the strainer from all sides. The debris must be added in a controlled manner as to not disturb the debris bed through unnecessary turbulence.

Progression The entire particulate debris load will be added at once for the thin-bed test. The debris load will be measured into buckets and mixed with water (tap or from the test tank) via an electric paint mixer until a slurry is prepared. Then, the fiber batches will be added incrementally per the test matrix. After all non-chemical debris is added, the chemical precipitate debris will be added. The chemical precipitates will first be mixed via an electric mixer or shaken and then will be added slowly into the tank, not exceeding approximately 10 gallons per minute. **The fiber and chemical debris loads may be adjusted at the discretion of the customer and test coordinator.** If the stabilized head loss is marginally less than the limiting head loss at the test temperature (19 ft-water, see Section 6.6), the next (non)chemical load may be decreased in order to enable an additional chemical load without exceeding the given head loss limit. This option allows smaller chemical load increments towards the end of the test to facilitate determination of the maximum allowable chemical load. These adjustments shall clearly noted in the test log if exercised.

Photos/Notes Photographs shall be taken at the end of each subtest if water condition allows. These photographs should show how the bed is forming onto the strainers and also document any settled debris. Notes shall be taken in the Test Log of all testing actions and observations, which shall include the test parameters (flow rate, dp across strainer, water temperature, turbidity, etc.) of that instant and the time. If actions continue beyond a small amount of time, the beginning and end of the action should be noted.

6.4 Data Acquisition

Electronic data acquisition must be controlled per the laboratory procedure as safety related. All test parameters must be recorded at least every 2 seconds and stored electronically in a tab delimited or Microsoft Excel file. This test data will be used in the Strainer Qualification report and does not require conditioning or filtering prior to that. During on-site storage, the test data shall be backed-up onto a local server or hard drive to prevent loss.

6.5 Test Matrix

The following sections describe in detail how to conduct each test. These test matrices are to be followed in order to accomplish the test plan objective. Any deviation from the given plans must be noted and rationalized in the test logs. See Section 6.6 and 7.0 for Stability and Termination Criteria.

6.5.1 Test #0 – Clean Screen Flow Sweep

With the tank filled to the appropriate water level at temperature, set the flow rate to the value and allow stability to be achieved (3 minutes). Record a data point before changing to the next flow rate. The final step consists of setting the flow at the target test flow rate.

Table 6-1: Clean Screen Flow Sweep Steps

Flow Sweep Step	Scaled Test Tank Flow (gpm)
Step 1 (Target Test Flow)	413
Step 2	375
Step 3	335
Step 4	295
Step 5	255
Step 6	375
Step 7 (Target Test Flow)	413

6.5.2 Test #1 – Debris Design Loading

Table 6-2: Test Matrix for Test #1

Subtest	Flow Rate (gpm)	Latent Fiber Fines (lbm)	Dirt/Dust Particulate (lbm)	Coatings Particulate (lbm)	AlOOH (gal)	Nominal Bed Thickness (in)
P.1	413	0	10.6	38.7	0	0
F.1	413	0.95	0	0	0	1/16
F.2	413	0.95	0	0	0	1/8
C.1	413	0	0	0	50	1/8
C.2	413	0	0	0	50[1]	1/8
C.3	413	0	0	0	50[1]	1/8
C.4	413	0	0	0	TBD[1]	1/8
V.1	413	Upon completion of the debris load testing the water level shall be reduced to 2.0 ft to check for vortexing.				
FS	Variable	Flow reduction in 100 gpm increments shall be performed to obtain pressure drop vs head loss data. These flow reductions can continue down to termination.				

Note 1: The maximum amount of chemical precipitate is 284 gallons. There are two potential outcomes from this test at this point.

Outcome 1: The addition of chemical precipitates do not produce any additional head loss, or cause the head loss to decrease. In which case as soon as the stabilization criteria is met or a peak is identified, the test may progress to the flow sweeps and termination.

Outcome 2: The chemical precipitates continue to increase the head loss as each batch is added and reach the limit of the system defined as 19 ft-water. In this case, the test should be secured at a steady state at an acceptable or reduced flow and the client will be notified on how to proceed.

6.6 Test Durations and Stability

Clean Screen Flow Sweep – The clean strainer head loss is measured at the flow rates given in Table 6-1. Each point is held for a minimum of 3 minutes.

P.1 Particulate Addition – The entire particulate debris load shall be added according to Table 6-2. The flow rate shall be maintained at 413 gpm for a minimum of 2 pool turnovers (PTO), based on tank volume.

F.1 Fiber Addition – The first fiber debris batch shall be added according to Table 6-2. The flow rate shall be maintained at 413 gpm for at least 10 PTO and a change in head loss less than 1% over a one-hour period.

C (Chemical Additions) – The chemical debris batches shall be added according to Table 6-2. The flow rate shall be maintained at 413 gpm for at least 10 PTO and a change in head loss less than 1% over a one-hour period.

FS (Flow Sweep) – The strainer head loss is measured at the reduced flow rates (decrements of 100 gpm) until the flow is stopped. Each point is held for a minimum of 2 PTO.

After the final flow sweep and required laboratory test completion procedures are fulfilled, the pump may be secured off, and Test #1 is complete.

7 TEST TERMINATION

In accordance with the test objective, the acceptance criterion for this testing is to successfully collect and record the specified test data.

Maximum Head Loss Limit – To prevent structural failure to the prototype or tank system, a head loss limit of 19 ft-water (10 psi x 80%) will be imposed during testing. If the head loss approaches this value, the test coordinator and customer must convene to decide the new flow rate of the system to maintain test continuance. The test vendor shall notify TPI of the hard limit of the test facility at which the flow must be reduced. Should the flow ever achieve this hard limit and the test operator require action, the flow should be reduced to maintain the flow at an acceptably high head loss, but less than the hard limit while TPI and test vendor determine new target flow rate. Under no circumstances should the test be aborted due to reaching a head loss limit unless a lower flow cannot be maintained.

7.1 Testing Stabilization Criteria

The head loss measurements for each test will be recorded and monitored continuously throughout the test. There are several stabilization points throughout each test that require different levels of stability as given in Sections 6.6. The test engineer and test coordinator must agree upon the fulfillment each Subtest criterion before continuing to the next Subtest. Furthermore, a note must be logged explaining why the Subtest is complete. Note that pool turnover times are based on water level and flow rate, and they must be calculated separately for each Subtest.

7.2 Atypical Head Loss Stability

In some cases, the head loss will stabilize atypically, or the head loss will be too low to calculate a 1% change. In these cases, the time period may be shortened or lengthened depending on test coordinator direction and client input. Whenever the head loss is declared as stable, a detailed note must be written on the test log that describes why the head loss was declared as stable before the next Subtest is initiated. If the above guidelines are modified, a more detailed note must be given in the test log that explains how and why the Subtest was declared as stable.

8 TEST DOCUMENTATION AND RECORDS

The Test Procedure shall provide the documentation for performing the required test steps and the associated signatures for the performance and witnessing of critical steps. The Test Procedure also provides for a test log, which is used to document significant points during the performance of the test. Test procedures shall be submitted to TPI for review and approval prior to testing.

The data acquisition system is used to collect flow rate, differential pressure, turbidity, and temperature data throughout the performance of the tests. This system also allows for the creation of graphs of the data as well as tables of the raw data. The electronic file of the raw data shall be provided to TPI on CD along with the final Test Report.

After testing is completed, a Test Report Summary document shall be prepared that contains the Test Logs, Test Data, Observations, and other pertinent information regarding the conduction of the tests. The following is table of contents for the Test Report that would be acceptable.

1. Introduction
2. Test Facility Description
3. Test Prototype
4. Debris Description
5. Test Procedure Summary
    a. Debris Preparation
    b. Test Setup
    c. Test Initiation
    d. Debris Addition
    e. Test Termination
    f. Post Test Observations
    g. Test Discrepancies and Nonconformance
6. Results of Testing
7. Quality Assurance
8. References

Appendix 1 – Test Log Sheets
Appendix 2 – Calibration Data Sheets
Appendix 3 – Material Data Sheets

9 QUALITY ASSURANCE REQUIREMENTS

This Test Plan is developed in accordance with Structural Integrity Associates Corporation's Quality Assurance Program and Procedures. The Test Procedure and subsequent qualification testing shall be conducted in accordance with an approved Quality Assurance Program that meets the requirements of 10 CFR 50 Appendix B. The results of the testing will be used in nuclear safety-related qualification documents.

9.1 Nonconformance, Corrective Action and Defects

Any nonconformance that arises during the test program shall be brought to the attention of the TPI Project Manager or his designee. In case of nonconformances affecting the test output, the test vendor shall notify TPI immediately and obtain their review and approval of the disposition.

9.2 Measuring and Test Equipment

M&TE used during testing must be within its valid calibration range and date. Certificates of conformance and calibration data must be available during testing. The data acquisition system and instrumentation must be verified to standards or some other method of checking prior to and after testing.

9.3 Lab Procedures

Lab procedures used during testing must be the most recent revision of each and each personnel working on the test must be fully trained and qualified to any procedures he or she is working to. Training logs to lab procedures and applicable project plans must available during testing.

10 REFERENCES

[1] APR1400-E-A-T(NR)-13001-P, APR1400 Design Features to Address GSI-191 Technical Report, Revision A, May 2013.

[2] USNRC, Regulatory Guide 1.82, Revision 4, "Water Sources for Long-term Recirculation Cooling Following a Loss-of-Coolant Accident", Washington D.C., March 2012.

[3] NRC Staff Review Guidance regarding Generic Letter 2004-02, “Closure in the Area of Strainer Head Loss and Vortexing,” U.S. Nuclear Regulatory Commission, Washington, DC, March 28, 2008. (ADAMS Accession No. ML080230038).

[4] Safety Evaluation for NEI Guidance Report 04-07, “PWR Sump Performance Evaluation Methodology,” U.S. Nuclear Regulatory Commission, Washington, DC. December 2004 (ADAMS Accession No. ML050550156)

[5] W.H. Ruland to J.C. Butler, “NRC Review of Nuclear Energy Institute Clean Plant Acceptance Criteria For Emergency Core Cooling Systems,” May 2, 2012 (ML120730181).

[6] NUREG/CR-6224, Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris, October 1995.

[7] “Final Safety Evaluation by the Office of Nuclear Reactor Regulation, Topical Report WCAP-16530-NP-A ‘Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids To Support GSI-191,’” U.S. Nuclear Regulatory Commission, Washington, DC, and Topical Report WCAP-16530-NP-A. (ADAMS Accession Nos. ML073520891 and ML08115037)

[8] Transco Strainer Prototype Drawing.