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TECHNICAL DOCUMENT COVER PAGE

Document No: ALION-PLN-STPEGS-8511-01	Revision: C	Page 1 of 13
Document Title: Test Plan for STP High Temperature Vertical Loop Testing		
Project No: 261-8511		
Project Name: STP Risk-Informed GSI-191		
Client: STPNOC		

Document Purpose/Summary:

This test plan documents the equipment, materials, controls and test variables for STP High Temperature Vertical Loop (HTVL) testing to:

1. Confirm the applicability of the NUREG/CR-6224 head loss correlation to the HTVL
2. Confirm the applicability of the NUREG/CR-6224 head loss correlation to STP specific conditions,
3. Determine the effects of Microtherm particulate.

This test plan is a draft document for preliminary discussions on the test matrix and protocol that will be used for the STP HTVL testing. Specific input values may be changed in the process of finalizing the test plan.

Design Verification Method:

__×__ Design Review

___ Alternative Calculation

___ Qualification Testing

Professional Engineer (if required) Approval _____Not Required_____ Date _____

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REVISION HISTORY LOG

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REVISION	DATE	Description
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TABLE OF CONTENTS

LIST OF FIGURES

1 BACKGROUND

South Texas Project Nuclear Operating Company (STPNOC) is developing the methodology for risk-informing the GSI-191 issue. One aspect of this effort entails the development of the CASA Grande software for analyzing the impact of a wide variety of high energy line breaks within containment. One module of CASA Grande is the head loss module that calculates the head loss across the ECCS strainer for given debris quantities and flow conditions. The CASA Grande head loss module relies on the NUREG/CR-6224 [7] head loss correlation to calculate the head loss across the strainer. However, the NUREG/CR-6224 head loss correlation was developed for higher approach velocities than the STP strainers. Also, some of the STP particulate to fiber mass ratios are outside the bounds of those used in developing the NUREG/CR-6224 head loss correlation, and the impact of Microtherm debris was not included in the development of the NUREG/CR-6224 head loss correlation. A series of tests using a vertical head loss test apparatus similar to the one used to develop the NUREG/CR-6224 correlation will provide the necessary data to appropriately implement the correlation in the CASA Grande head loss module.

2 TECHNICAL APPROACH

Testing will be performed in the high temperature vertical loop (HTVL) at the Alion Science & Technology hydraulics laboratory located in Warrenville, IL. The HTVL is described in Section 4.

Fluid will be circulated in a closed loop at ambient temperature for each test case, and debris will be added to the loop to form a debris bed on a circular section of perforated plate. The head loss across the debris bed will be monitored as it stabilizes. A flow sweep will be performed following head loss stabilization. A NUREG/CR-6224 head loss correlation calculation will be performed for each test case and the results will be plotted and compared. As needed, modifications to the NUREG/CR-6224 head loss correlation will be developed to better match the experimental results. All results will be documented in a test report.

3 TEST OBJECTIVES

The objective of all tests is to collect steady state head loss data for the STP flow and debris loads. A total of six tests will be performed:

STP-1: NUREG/CR-6224 Applicability to the HTVL – Tap Water
Test with nominal fiber, particulate, and approach velocity used in the derivation of the NUREG/CR-6224 head loss correlation to verify the applicability of the NUREG/CR-6224 head loss correlation to the HTVL.

STP-2: NUREG/CR-6224 Applicability to the HTVL – STP post-LOCA fluid chemistry
Repeat of STP-1 with STP specific post-LOCA water chemistry to determine the impact of water chemistry on the NUREG/CR-6224 head loss correlation.

STP-3: STP Nominal Debris Load Test
Nominal debris load test at STP flow and post-LOCA water chemistry to verify the applicability of the NUREG/CR-6224 head loss correlation to STP specific conditions.

STP-4: STP High Fiber Test
High fiber test at STP flow and post-LOCA water chemistry to verify the applicability of the NUREG/CR-6224 head loss correlation to STP specific conditions.

STP-5: STP High Eta Test
High particulate-to-fiber mass ratio (eta) test at STP flow and post-LOCA water chemistry to verify the applicability of the NUREG/CR-6224 head loss correlation to STP-specific conditions.

STP-6: STP Microtherm Test
Test with the addition of a nominal quantity of Microtherm to the STP-3 test conditions to verify the applicability of the NUREG/CR-6224 head loss correlation.

4 HTVL INFORMATION

A diagram of the High Temperature Vertical Loop (HTVL) and instrumentation is provided in Figure 4-1, and a photo is provided in Figure 4-2.

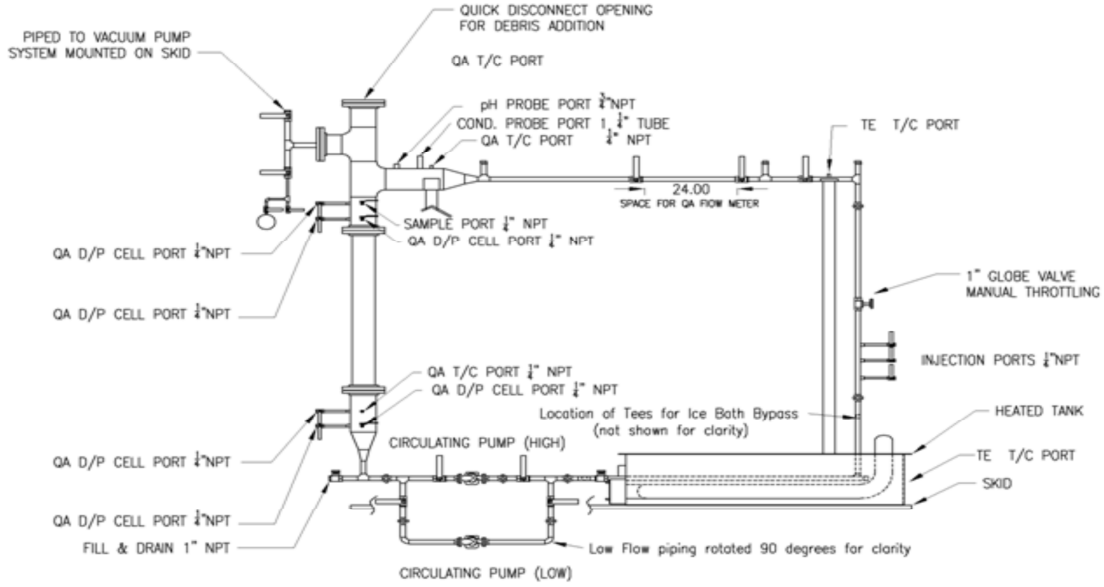

Figure 4-1 – High Temperature Vertical Loop Schematic

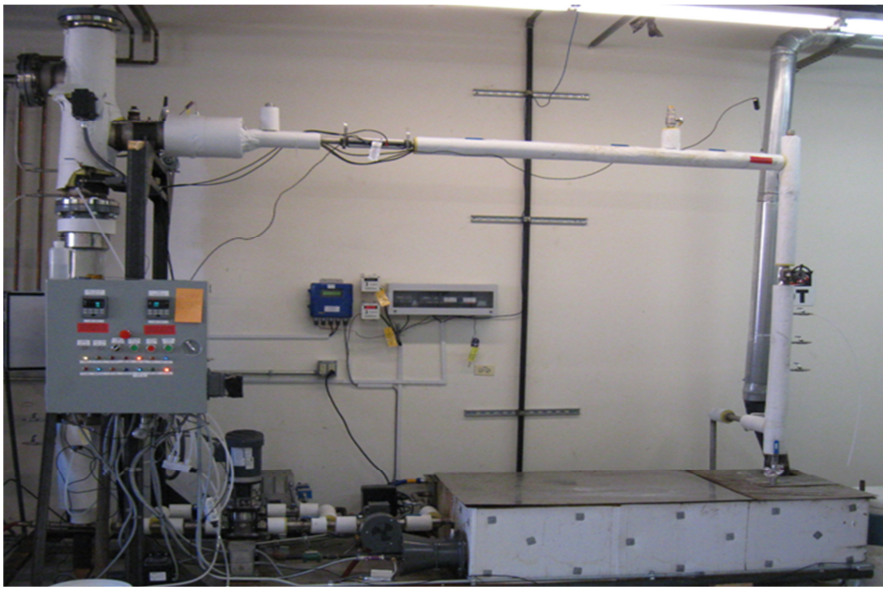

Figure 4-2 – Photograph of High Temperature Vertical Loop

Standard procedures will be used to control the general loop operation [1, 2, 3, 4, 5, 6]. The debris will be introduced at the open top of the loop and will be uniformly distributed on the horizontal screen located in the middle section of the vertical pipe. Water will be circulated at prescribed flow rates while temperature and the differential pressure are measured.

4.1 TEST SCREEN AND SCALING

The test screen is a perforated plate that supports the debris bed and imparts minimal clean screen head loss. The screen area of the test screen is 0.196 ft^2 and has 3/32nd inch holes.
The STP strainer has a surface are of 1,818.5 ft^2 per train, and also has 3/32nd inch holes. The scaling factor for debris is simply the ratio of the surface areas: 1.078×10^{-4}. Table 4-1 lists the screen surface area, strainer surface area, and scaling factor used in testing.

Table 4-1 – Screen Areas and Scaling Factor

Plant Strainer Area	1,818.5 ft^2
HTVL Plate Area	0.196 ft^2
Scaling Factor	1.078×10^{-4}

4.2 WATER CHEMISTRY

Tests will be conducted using borated, buffered, reverse osmosis (RO) water representative of the STP post-LOCA sump water chemistry. The exact water chemistry will be based on an evaluation of the nominal post-LOCA conditions. The base coolant composition is specified in Table 2.

Table 2: Base Coolant Composition

Component	Quantity / Test Value	Molar Mass	Plant Component
Reverse Osmosis Water	60.0±0.25L	18.016 g/mol	Sump Water
Boric Acid (H_3BO_3)	TBD	61.834 g/mol	TBD
Target pH	7.5	n/a	Plant pH ranges from 7.1 to 7.9
TSP	TBD	TBD	TBD

4.3 WATER TEMPERATURES

The fluid temperature to be used in testing will be ambient within the range of 50 – 90°F.

4.4 TEST DEBRIS

- Fiber debris shall be single-side baked (SSB) Nukon with an as-fabricated density of 2.4 lb_m/ft^3.
- The simulant for all particulate debris (with the exception of Microtherm) shall be silicon carbide with a nominal 10 micron diameter and a particulate density of 199.68 lb_m/ft^3.

4.5 TEST DEBRIS PREPARATION

The debris mixture shall be prepared as follows:

1. Measure out the weight of SSB Nukon fiber specified in Table 5
2. Prepare the fiber debris in accordance with the NEI Fiber Debris Preparation Guideline Rev 2 using RO water
3. Drain and rinse fiber with cold RO water
4. Remove 2L of liquid from the HTVL
5. Add test fiber to 2L of liquid in a glass container
6. Agitate using a stirring rod for two minutes
7. Test Engineer: Visually examine the resulting slurry and ensure that no clumps of wetted insulation exist. Prepared fiber shall be photographed using a light table to document the prepared fiber size distribution. The photographed fibers shall be returned to the glass container and the glass tray used to photograph shall be rinsed with liquid from the HTVL and added to the glass container.
8. At the completion of photographing the fiber slurry and re-introduction of the photograph fibers to the glass container, agitate the suspension using a stirring rod for 1 minute.
9. Slowly add the silicon carbide powder quantity specified in Table 5 to the fiber slurry while agitating the fiber slurry using a stirring rod. After completion of the addition of the silicon carbide continue the agitation of the slurry for 2 minutes. Visually examine to ensure no clumping of either debris type occurs.
10. Continue agitation until slurry is added to the test loop

4.6 DEBRIS INTRODUCTION

The debris mixture prepared in Section 4.5 shall be introduced into the HTVL at the flanged opening directly over the screen. The debris slurry fiber-particulate mixture from the mixing container must be added very slowly to the opening in the HTVL over a period of at least one minute. The slurry mixture shall be poured very slowly around the internal periphery of the opening to facilitate uniform bed thickness formation. While pouring the mixture, the slurry shall be agitated with the stirring rod to ensure homogeneity of the mixture. If clumps form in the mixing container, debris addition shall be stopped momentarily to stir the debris mixture in the beaker with a stirring rod to re-suspend debris as necessary.

5 TEST MATRICES

Debris loads were calculated using Equation 2.

$$DebrisTest_i = DebrisPlant_i \times \frac{Area_{HTVL}}{Area_{Plant}} \quad (2)$$

The STP strainer nominal parameters are a flow of 7,020 gpm passing through a screen with a nominal 1,818.5 ft^2 surface area. The following Test Matrices detail the six HTVL tests.

Table 5: Test Matrix

Test Number	Approach Velocity (ft/s)	Water Chemistry	Eta	Nukon (g)	Silicon Carbide (g)	Micro-therm (g)
STP-1	0.5	Tap	5	16	80	0
STP-2	0.5	RO/Boron/TSP	5	16	80	0
STP-3	0.009	RO/Boron/TSP	5	16	80	0
STP-4	0.009	RO/Boron/TSP	0.5	160	80	0
STP-5	0.009	RO/Boron/TSP	40	4	160	0
STP-6	0.009	RO/Boron/TSP	5.1	16	80	1

Testing will proceed according to the parameters outlined in this document and all applicable procedures. During testing, actions will be guided by the test-specific procedures.

6 TEST PROCEDURES

Alion has developed generic test procedures for head loss testing. These generic test procedures are applicable and the current revisions at the time of testing will be used to perform the testing specified in this test plan. The following is a list of the generic test procedures:

- ALION-SPP-LAB-2352-21 – Test Lab Safety Procedure
- ALION-PLN-LAB-2352-01 – GSI-191 Testing and Examination of Materials
- ALION-SPP-LAB-2352-26 – High-Temperature Vertical Loop Filling, Draining, and Cleaning Procedure
- ALION-SPP-LAB-2352-28 – High-Temperature Vertical Loop Debris Head Loss Procedure
- ALION-SPP-LAB-2352-13 – Test Equipment Verification Procedure
- ALION-SPP-LAB-2352-14 – Testing Discrepancies

For each of the tests, the general sequence of each test is as follows:

1. Install perforated plate in the HTVL.
2. Fill test loop in accordance with ALION-SPP-LAB-2352-26 – "High-Temperature Vertical Loop Filling, Draining, and Cleaning Procedure" utilizing tap or RO water in accordance with the test matrix.
3. If necessary, adjust the water chemistry in accordance with Section 4.2
4. Prior to head loss testing, test equipment should be verified through the Test Equipment Verification Procedure, ALION-SPP-LAB-2352-13.
5. Prepare debris in accordance with Section 4.5.
6. Introduce the debris in accordance with Section 4.6.
7. Conduct strainer head loss testing in accordance with ALION-SPP-LAB-2352-28 – "High-Temperature Vertical Loop Debris Head Loss Procedure", and the test matrix described in Section 5.
8. Drain and clean the chemical test loop in accordance with ALION-SPP-LAB-2352-26 – "High-Temperature Vertical Loop Filling, Draining, and Cleaning Procedure".
9. At all times the Test Lab Safety Procedure, ALION-SPP-LAB-2352-21 shall be followed.

7 TEST EQUIPMENT

The details of the equipment used and the calibration of the following instruments in this testing is identified and controlled in the Test Program Description [4]. Table 7-1 summarizes the instrumentation that will be used in testing.

Table 7-1 – HTVL Test Equipment

Instrument	Specifications
Scales	0 to 13.2 lbs range, +/- 0.005 lbs readability
Balance	0 to 600 grams range, +/- 0.01 g readability
Pressure Transmitters	0 to 100 inches H_2O, accuracy 0.25% of span
Ultrasonic Flow Meter	0.1 fps to 40 fps range, +/- 1% of reading at rates above 1 fps and +/- 0.01 fps of reading rates lower than 1 fps
Thermocouples	32˚F to 1652˚F range, +/- 1%
pH Probe	pH range of 0 to 14, +/- 0.02 pH units

7.1 TEST ACCEPTANCE AND TERMINATION CRITERIA

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

7.2 HEAD LOSS STABILIZATION

The following head loss stabilization criteria shall be used for this test program:

- If the head loss is ≥ 2.0 ft-H_2O (24 in-H_2O):

  The stability requirement is met if the difference in the head loss over the course of **1 hour** is less than1% of the head loss value as computed by LabView, which will be programmed to track the percentage difference over one hour.

- If the head loss is <2.0 ft-H_2O (24 in-H_2O):

  The stability requirement is met if the difference in the head loss over the course of **1 hour** is less than 0.24 in-H_2O as computed by LabView, which will be programmed to track head loss difference over one hour.

8 TEST DOCUMENTATION AND RECORDS

The test procedure provides 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. The data acquisition system is used to collect flow rate, differential pressure 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.

9 DEBRIS HANDLING REQUIREMENTS

This test plan identifies a test matrix using Nukon, silicon carbide, and Microtherm. According to the Material Safety Data Sheets provided with the purchased debris material, the following must be used when handling the debris:

- Safety glasses with side shields or goggles must be worn.
- Cloth or Tyvek laboratory coat
- Dust masks with a N95 rating like 3M Model 8210
- Latex, nitrile or neoprene gloves – leak check gloves before use
- Recommends long sleeved shirt & pants.
- Fire extinguisher with water, foam, carbon dioxide or dry power for the debris.

10 REFERENCES

1. ALION-SPP-LAB-2352-21 – Test Lab Safety Procedure, Rev. 5.
2. ALION-SPP-LAB-2352-26 – "High-Temperature Vertical Loop Filling, Draining, and Cleaning Procedure"
3. ALION-SPP-LAB-2352-28 – "High-Temperature Vertical Loop Debris Head Loss Procedure"
4. ALION-PLN-LAB-2352-07, "Hydraulic Testing of Debris Program Description: High-Temperature Vertical Loop"

5. ALION-SPP-LAB-2352-13 – Test Equipment Verification Procedure, Rev. 8.
6. ALION-SPP-LAB-2352-11 – Procurement of Materials, Components and Services, Rev. 3.
7. NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris", October 1995.