CHEMICAL EFFECTS HEAD LOSS EXPERIMENT (CHLE) TEST PROTOCOL for Calvert Cliffs Nuclear Power Plant

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1.0 PURPOSE

The purpose of this document is to describe the protocol planned to be implemented for the chemical effects head loss experiments (CHLE) for the Calvert Cliffs Nuclear Power Plant (CCNPP). This document presents the methods for performing the experiments, the processes for which the test conditions for each experiment will be established, and the methods for applying the experimental results. The plan for performing these experiments is described in a separate document.

2.0 EXPERIMENTAL OBJECTIVES

The objective of the overall experimental program is to define the impact of chemical effects on debris bed head loss at CCNPP. The specific objective of the initial experiments is to determine the impact of chemical effects on debris head loss. The initial experiments are designed to test design basis bounding conditions for possible deterministic resolution of GSI-191. If chemical effects induced head loss is observed in these tests that cannot be accounted for by adding margin to emergency suction strainer and long term core cooling performance, the test program will be expanded to support a risk-informed approach to GSI-191 resolution.

3.0 OVERALL EXPERIMENTAL PROTOCOL

The overall concept for the experiments is a long-term integrated chemical effects test with head loss measured throughout the test. Materials used in the test will be representative of the materials submerged in the containment pool and/or exposed to containment spray. These include destroyed insulation, qualified/unqualified coatings, concrete, latent debris and other potentially reactive materials in containment. The material quantities will be scaled such that the ratio of the test fluid volume or mass to the volume or mass of materials immersed in the pool fluid or the surface area of materials exposed to pool or spray fluid is consistent with the ratio of the volume or mass of the post-LOCA pool to the submerged material volume or exposed material surface area at CCNPP. This will maintain consistent chemistry concentrations.

The test chemistry will begin with the initial post-LOCA pool chemistry expected at CCNPP. A scaled quantity of sodium tetraborate decahydrate (NaTB) buffer will be allowed to dissolve in the test chamber to simulate the dissolution of buffer in the plant. Strong acids from the radiolytic decomposition of water and electrical cables will be added periodically to the test at a rate similar to which these acids are expected to be produced at CCNPP. No additional chemical or pH control will occur. The test chemistry will be allowed to evolve as it would in the post-LOCA environment at CCNPP. Water chemistry will be periodically sampled and tested for chemical contents.

The test temperature conditions will simulate the CCNPP post-LOCA temperature profile for the specific break conditions being simulated in the experiment, with the exception of the initial high temperature portion of the event. This initial high temperature portion of the event is discussed in Section 5.3. The last portion of the test will be used to investigate low temperature chemical effects by reducing the temperature in stages until room temperature is achieved.

Head loss will be monitored throughout the test using a fiber and particulate debris bed formed on a flat perforated plate that has proven to be a good detector of head loss caused by chemical effects [Ref. 1]. The debris bed will not necessarily be representative of the debris bed expected on the sump strainer or within the reactor core at CCNPP but it will include similar fibrous material. The flow rate through the debris bed will yield a higher approach velocity than that expected at the CCNPP sump strainer and fuel assemblies. The flow rate used will be specified to increase the sensitivity of the debris bed for identification of head loss due to chemical effects.

4.0 EXPERIMENTAL FACILITY DESIGN

The planned design of the experimental facility includes the following major components:

1) Reaction Chamber – This chamber contains the material coupons and buffering agent and is used to simulate the containment pool for the long-term test. Test chamber allows for full submergence of coupons as well as exposure to nozzles simulating containment spray. The chamber will include six mesh baskets to contain the granular buffer material.
2) Vertical Head Loss Loop – This loop contains the flat perforated plate and debris bed across which chemical effects head loss will be detected.
3) Heat Exchanger Loop – This loop contains a cool-down heat exchanger to investigate the potential for chemical precipitation in the shutdown cooling heat exchangers.
4) Primary Heater – This heater controls the temperature of the reaction chamber and heats recirculation fluid from the head loss and heat exchanger loops prior to injection into the reaction chamber.
5) Recirculation Pumps and Valves – The reaction chamber, vertical head loss loop, and heat exchanger loop have independent recirculation pumps with valves to control flow direction.
6) Initial Solution Preparation Chamber – This chamber contains the initial borated water solution simulating the reactor coolant and safety injection fluid and will be discharged into the reaction chamber at the beginning of each experiment to simulate the LOCA.

A schematic diagram of the planned loop is shown in Figure 1 below. Four different operation modes of the loop are shown in Figure 2 through Figure 5.

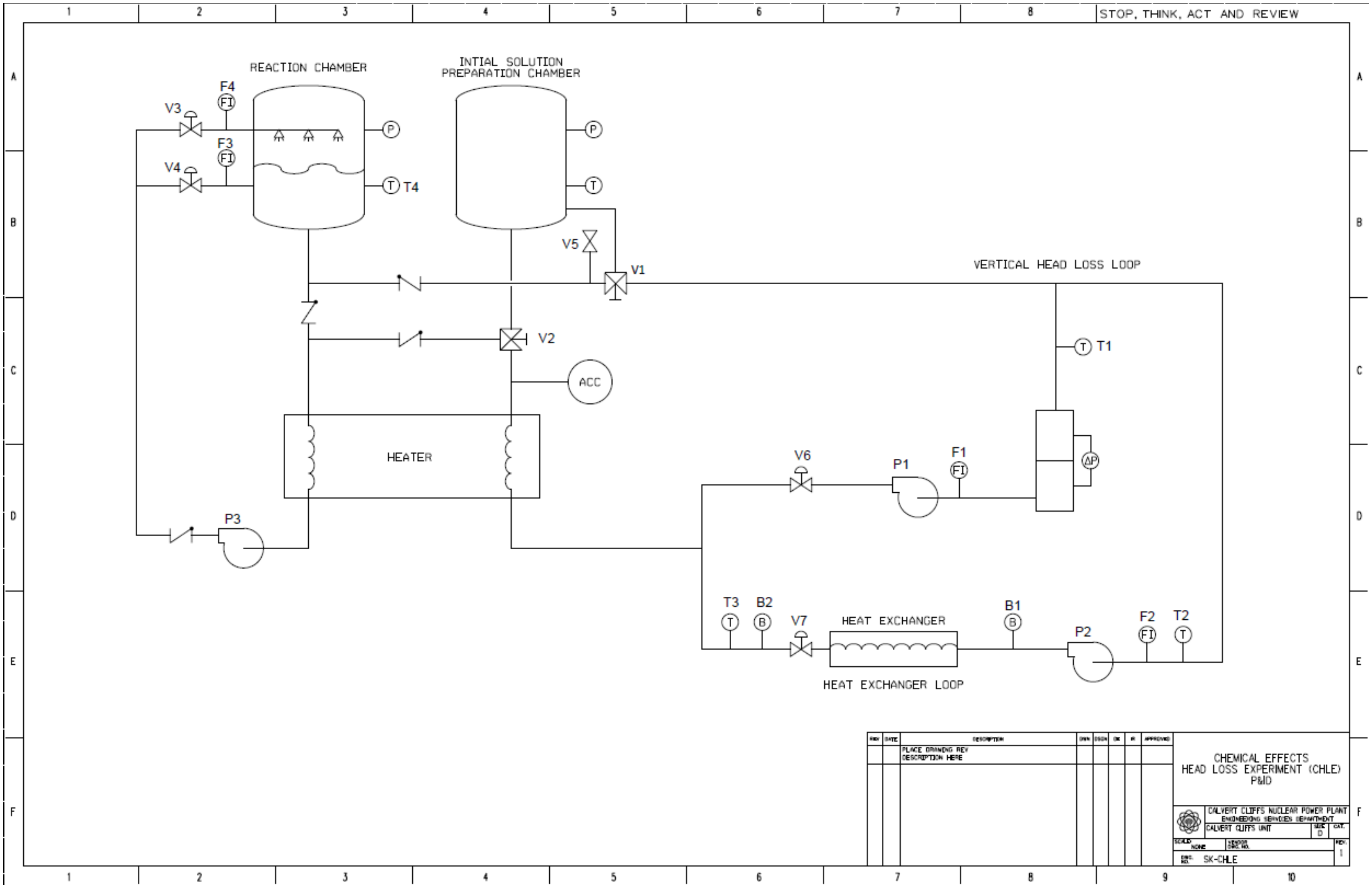


Figure 1: Schematic of Proposed CHLE Facility

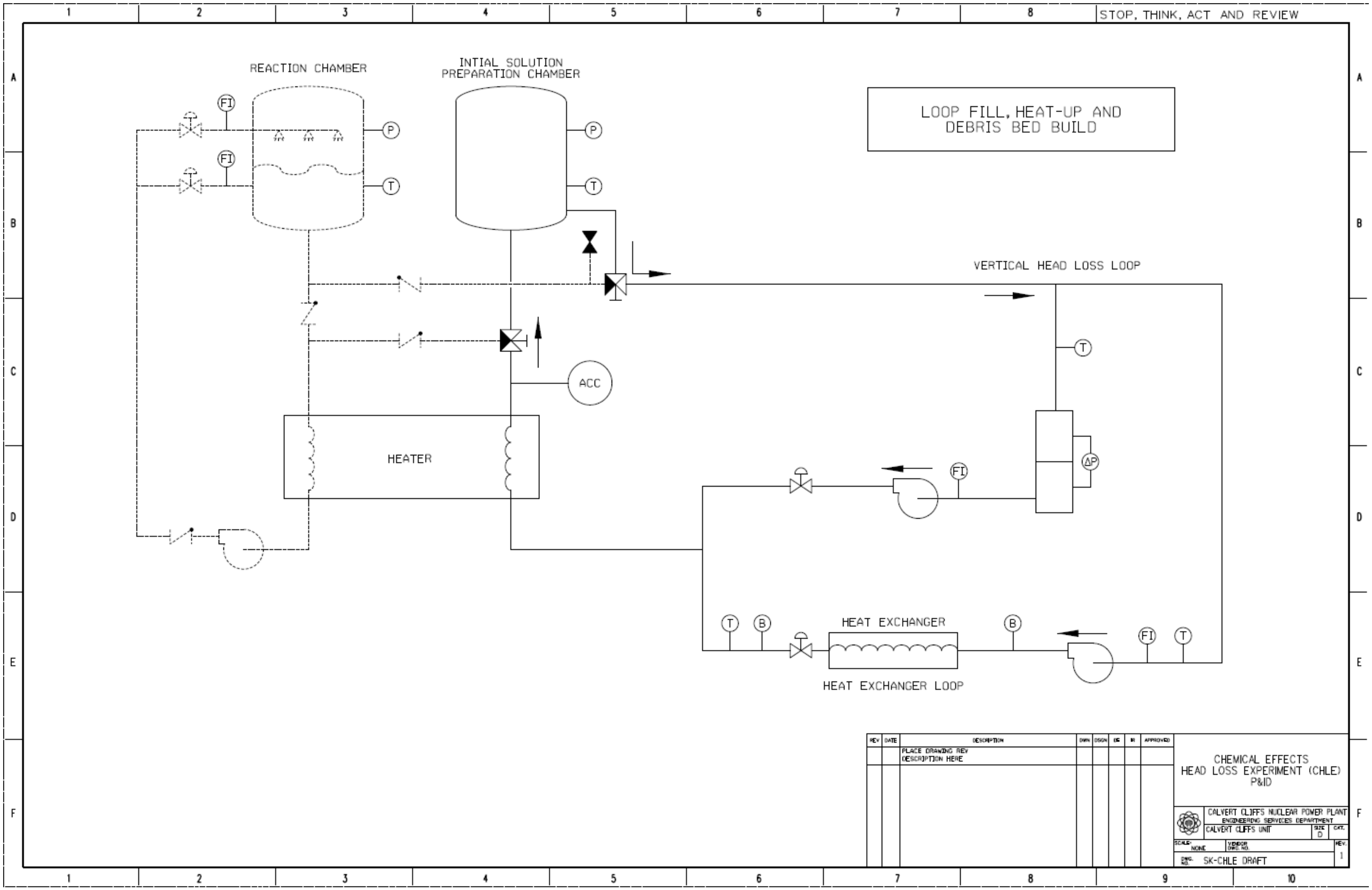


Figure 2: Loop Fill, Heat-Up and Debris Bed Build

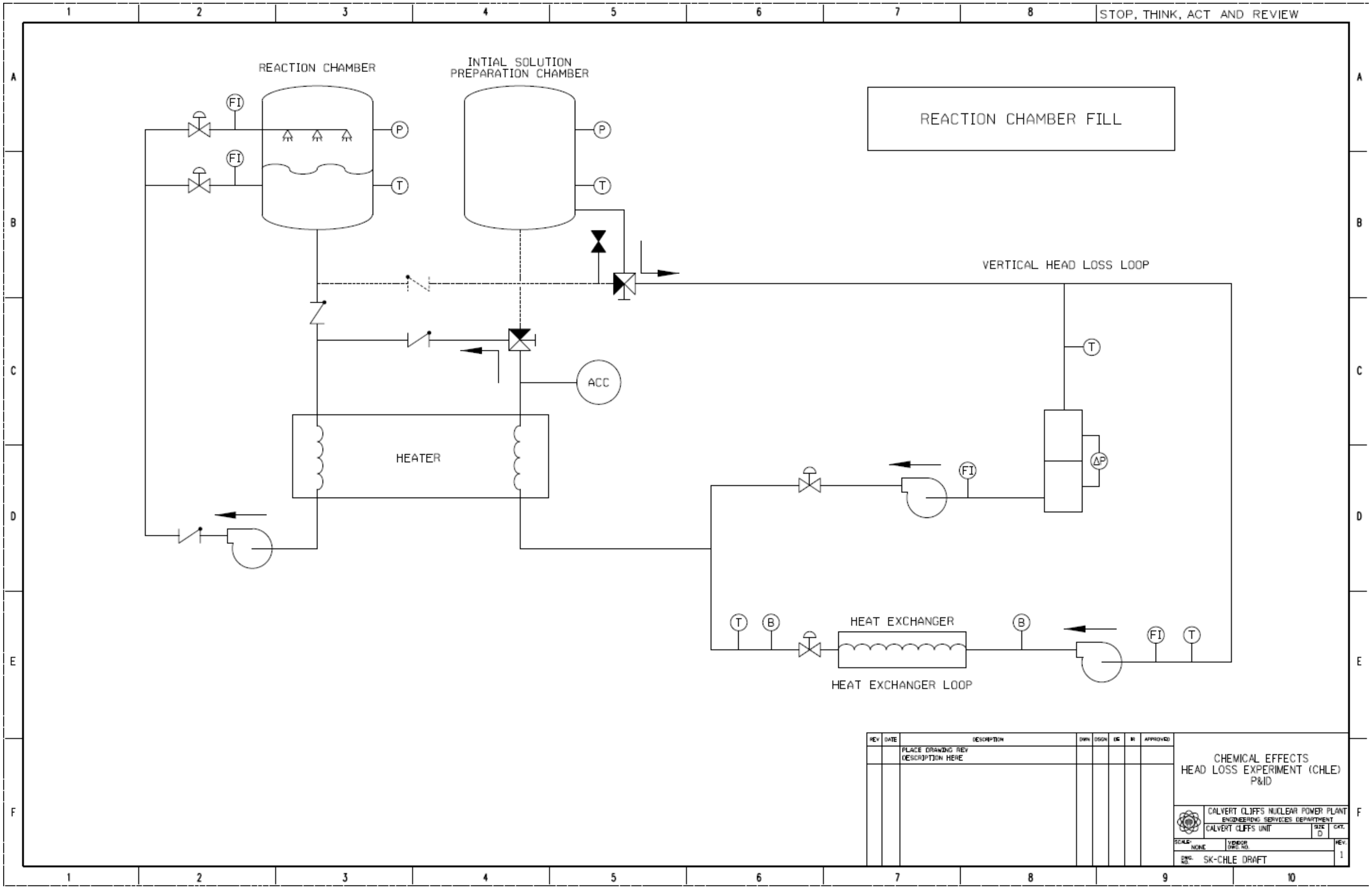


Figure 3: Reaction Chamber Fill

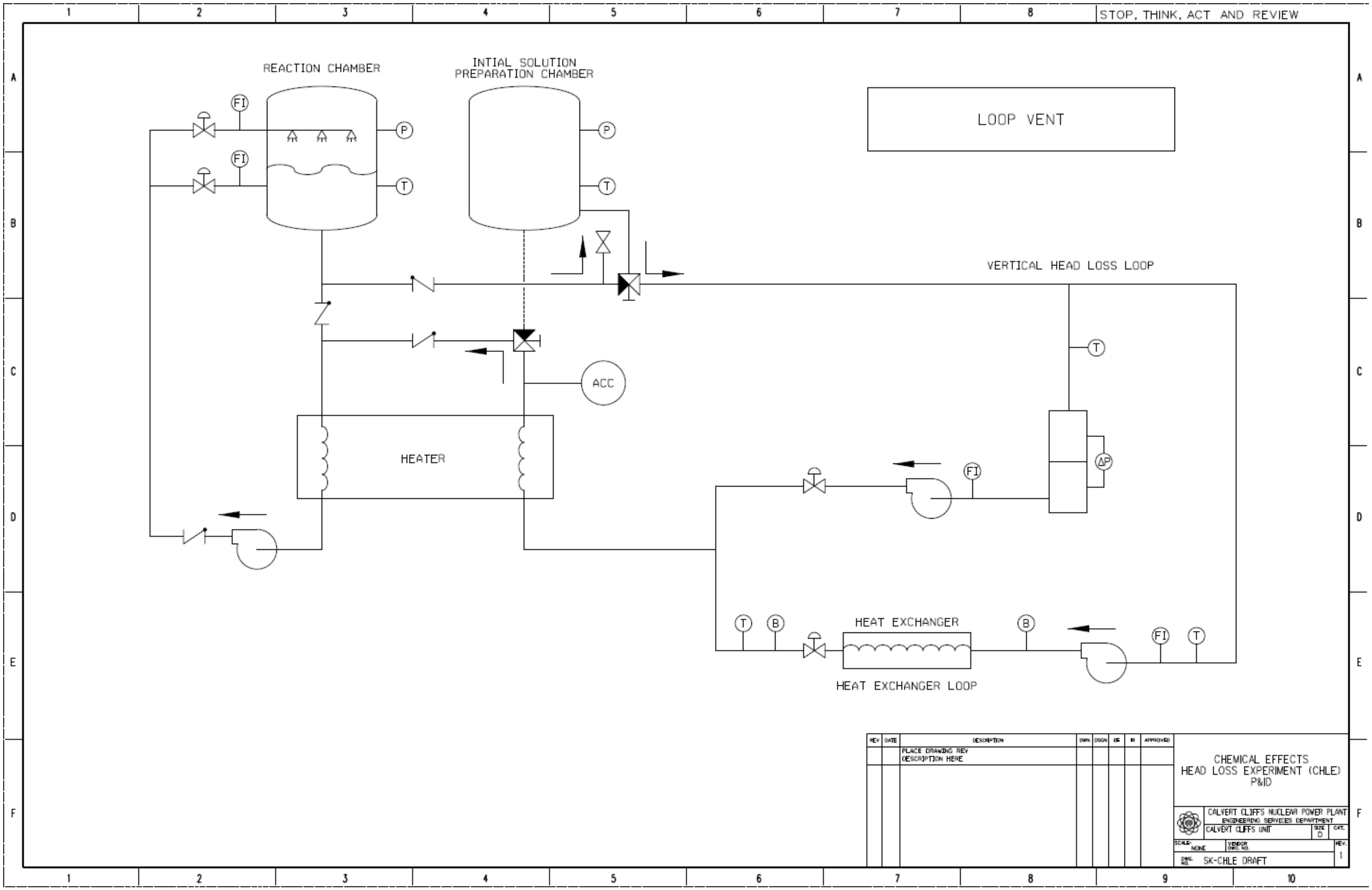


Figure 4: Loop Venting

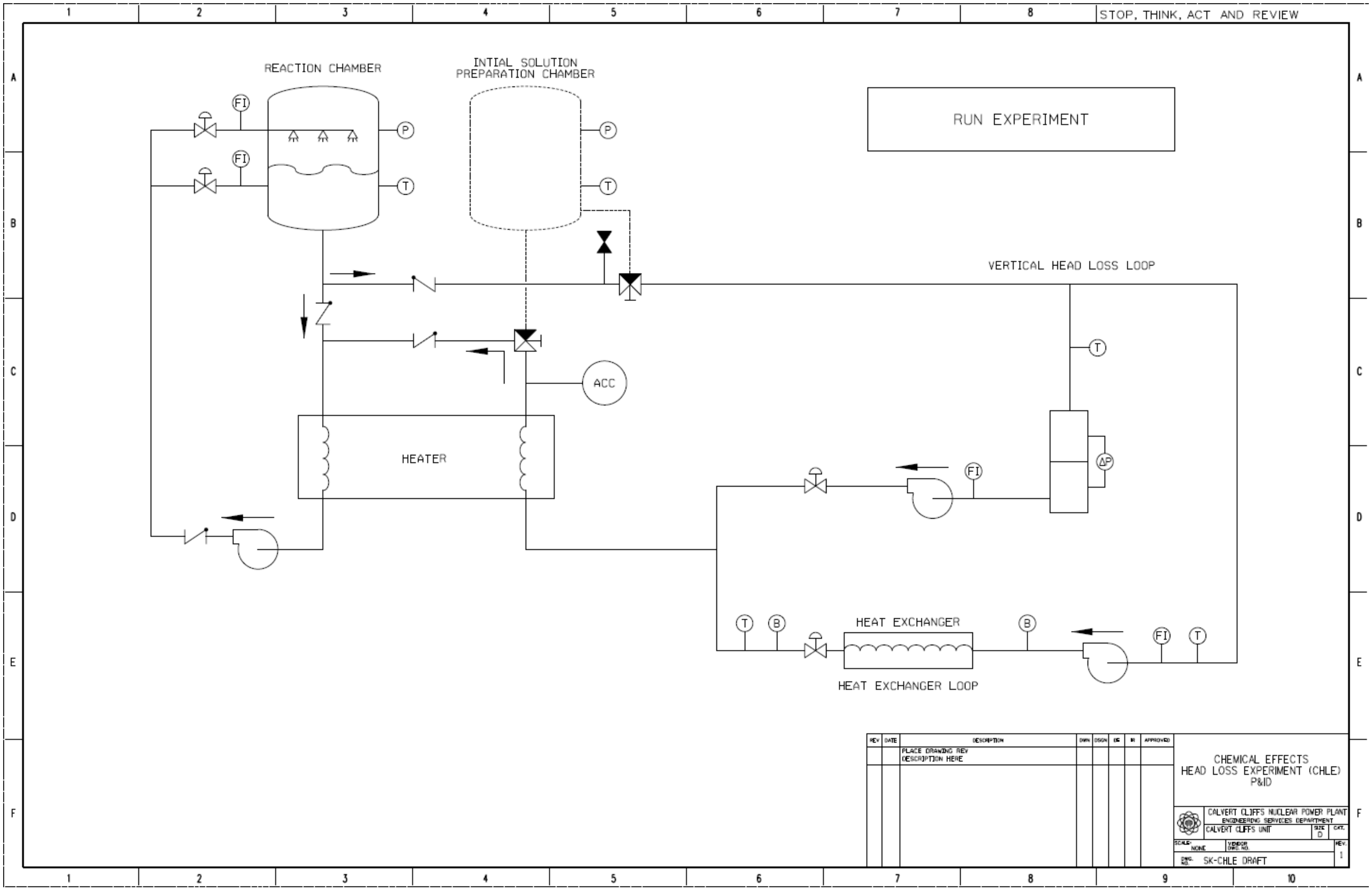


Figure 5: Loop Run

5.0 SPECIFIC EXPERIMENTAL PROTOCOLS

5.1 Debris Preparation and Introduction

5.1.1 Fibrous Debris

Fibrous debris, other than the fiber in the vertical head loss loop debris bed, will be prepared in accordance with the NEI protocol [Ref. 2], with the exception of steps 6.6 and 6.7, dried, and weighed to the quantity specified in the test plan. The water used for soaking in step 6.5 of the NEI protocol shall be deionized water. The fiber samples will be placed in stainless steel mesh containers or otherwise secured to prevent fiber migration into the vertical head loss or heat exchanger loops which could affect head loss in the debris bed.

5.1.2 Marinite and Concrete Debris

Marinite and concrete debris will be cut from a solid piece into pieces no larger than 2" x 2" x 0.5" thick. The samples may include smaller particles, none of which can pass through a 16 mesh sieve. The samples will be placed in stainless steel 18 mesh containers and secured to remain submerged in the experimental fluid and to prevent migration into the vertical head loss or heat exchanger loops which could affect head loss in the debris bed.

5.1.3 Coatings

Epoxy coatings debris generated from exposure to the break jet will be prepared by applying the coating to a flexible surface, peeling the coating off the flexible surface after drying and then pulverizing the coating into chips less than 0.5" and greater than 0.25" per side. The chips will be placed in stainless steel 18 mesh containers and secured to remain submerged in the experimental fluid and to prevent migration into the vertical head loss or heat exchanger loops which could affect head loss in the debris bed. Inorganic zinc coatings debris generated from exposure to the break jet will be simulated by using inorganic zinc coated coupons with a surface area equivalent to the surface area of the quantity of 10 μm spherical particles calculated to be produced for each break.

Unqualified coatings not exposed to the break jet will be applied to a coupon of substrate similar to that which they are applied at CCNPP. The coupons coated with the surface area specified in the test plan will be introduced into the reaction chamber prior to initiation of each experiment. These coated coupons will be allowed to dissolve and/or corrode normally in the experimental solution.

5.1.4 Reactive Materials

Coupons of reactive materials (aluminum, galvanized steel, and copper) will be prepared from 10 gauge or thinner flat plates, weighed, and placed in the reaction chamber prior to initiation of each experiment. These coupons will be submerged in the fluid and/or suspended above the fluid exposed to spray and allowed to dissolve and/or corrode normally in the experimental solution.

5.2 Fluid Chemistry

The fluid chemistry will be established in the initial solution preparation chamber and will match the borated water lithium hydroxide solution expected in the containment pool at the beginning of the LOCA. Silica will not be included as the silica concentration is very low, less than 2 ppm, relative to the silica concentration expected from dissolved fiberglass insulation.

The NaTB buffer will be placed in the reaction chamber prior to the initiation of each experiment and will be allowed to dissolve naturally in the experimental fluid. Strong acids from the radiolytic decomposition of water and electrical cables will be added periodically to the test at a rate similar to which these acids are expected to be produced at CCNPP. No additional chemical or pH control will occur.

5.3 Fluid Temperature

The fluid temperature will simulate the sump temperature profile for the CCNPP containment response analysis of record (AOR) [Ref. 3] with a variance of -0°F, +5°F for 720 hours (30 days). The sump temperature profile for the initial 8.3 hours of the LOCA is above 195°F. CCNPP performed an autoclave test [Ref. 4] that demonstrated that a steady fluid temperature of 195°F for 22 hours resulted in a comparable or greater concentrations of key elemental species as those produced during the initial 10 hours of the CCNPP AOR sump temperature profile. Therefore, the temperature in the experiments for the initial 720 hours will be that shown in Table 1 and Figure 6.

Table 1: 30 Day Fluid Temperature Profile

Time (hr)	Test Temperature	AOR Sump Temperature
0.03	195	271.8
8.34	195	194.8
22	195	174.4
100	165	159.7
200	155	150.3
300	150	146.3
400	150	145.1
500	148	142.3
600	145	141.0
700	145	141.0
720	145	141.0

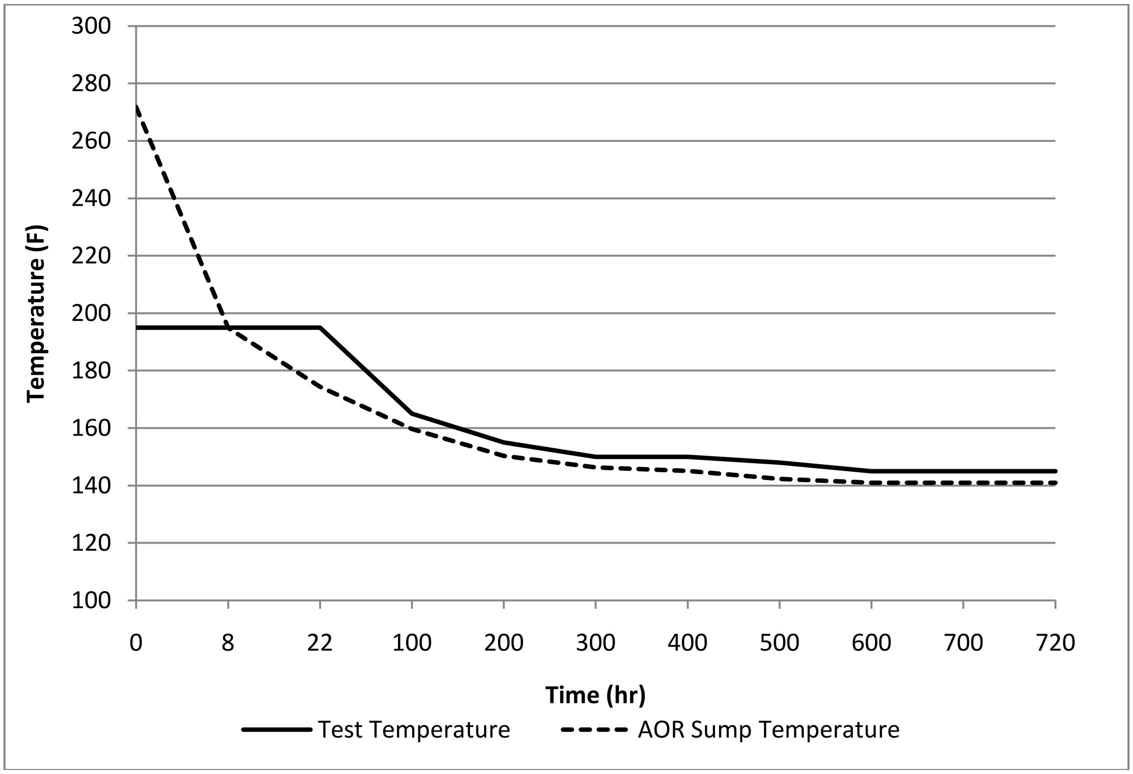


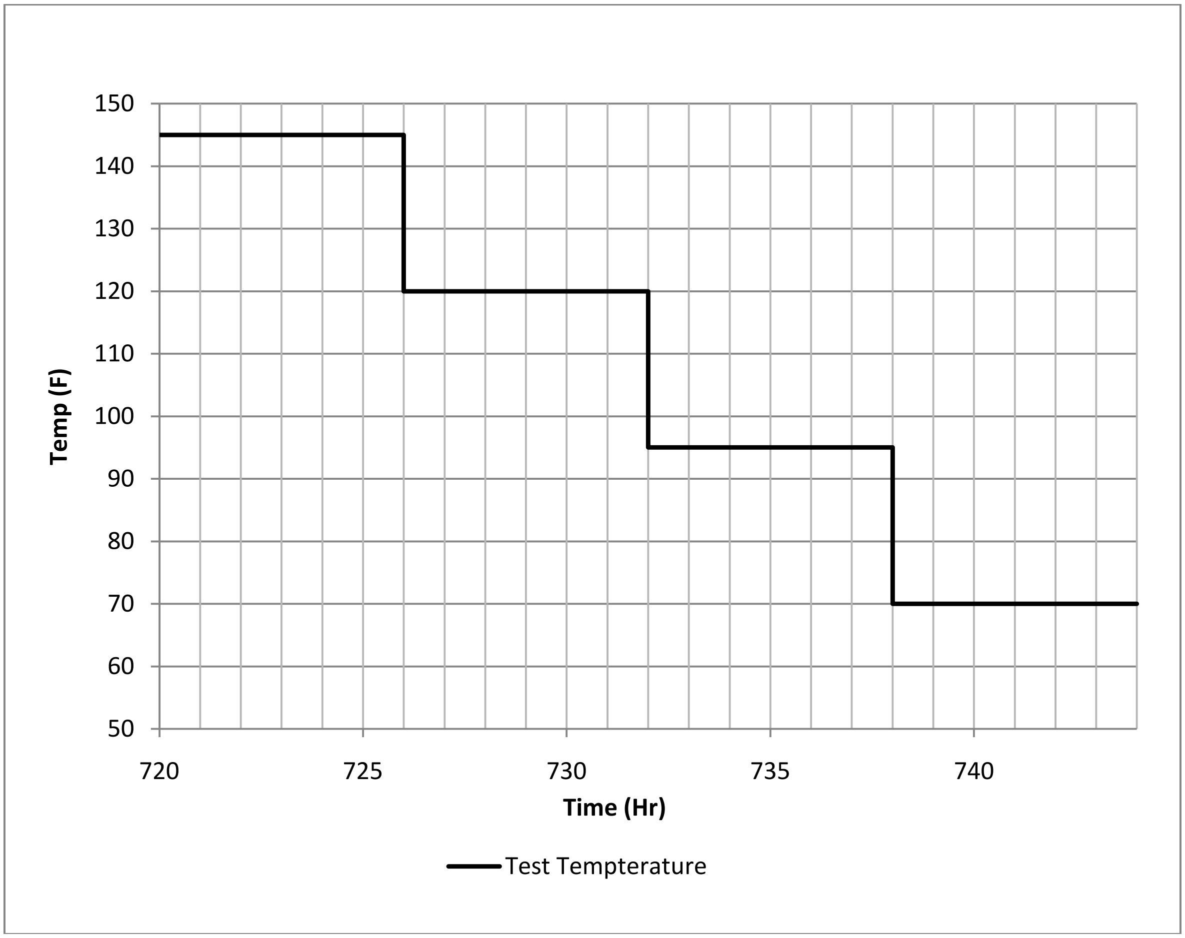
Figure 6: 30 Day Fluid Temperature Profile

The last day of the test will be used to investigate low temperature chemical effects by reducing the temperature in stages until room temperature is achieved. Therefore, the temperature in the experiments for the final 24 hours will be that shown in Table 2 and Figure 7.

Table 2: Temperature Profile Final Day

Time (hr)	Test Temperature (°F)
720.00	145
726.00	145
726.00	120
732.00	120
732.00	95
738.00	95
738.00	70
744.00	70

Figure 7: Temperature Profile, Final Day



Aluminum solubility tests performed by Argonne National Laboratory visually observed prompt precipitation after temperature decreases [Ref. 5, Appendix A]. The qualitative visual observations did not indicate continued precipitation, nor were any cases shown where precipitation occurred after a significant time delay while holding at a constant temperature. Additionally, since the experiment will be run for 30 days at post-LOCA temperatures, it is assumed that any predecessor reactions will have sufficient time to progress to completion. Although the temperature stages are intended to simulate low sump temperatures within the 30-day mission time, a full 30 days of corrosion/dissolution at higher temperatures and continued corrosion/dissolution at each temperature stage ensure that the elemental concentrations will be conservatively high. Lastly, precipitation will likely occur between temperature stages. Therefore, the preceding temperature stage will be conservatively credited as the temperature at which chemical effects head loss occurs if chemical effects head loss is observed during the temperature reduction. For these reasons, the holding of each temperature stage for 6 hours is assumed to be acceptable for the observation of chemical effects head loss.

5.4 Head Loss Measurement

Chemical effects head loss will be indicated by measurement of head loss across a debris bed. The debris bed formed on the six inch diameter flat plate screen is intended to provide a highly efficient filtering media capable of readily identifying the head loss impact of potential precipitates on a qualitative basis. Since the head loss that is being monitored during the course of the test is meant to provide only a qualitative indication of chemical effects impact, the composition of the bed is designed more for filtering and not as a prototypical debris bed for CCNPP. The goal in the debris bed formation is to establish a stable head loss prior to the beginning of the integrated test.

Table 3: Detector Debris Bed Composition

Substance	Quantity (in grams)
NUKON	16 ± 0.1
F600 Green Silicon carbide	80 ± 0.1

The debris loading for this particular configuration results in a particulate to fiber mass ratio of 5:1.

This detector debris bed was developed during vertical loop head loss testing in late 2008 and early 2009 [Ref. 1]. The debris bed was found to provide repeatable head loss results and was sensitive to detecting head loss from chemical precipitates.

The debris mixture is prepared as follows:

1. Blanket NUKON will be double-shredded to produce fines;
2. The fiber will be boiled for 10 minutes in deionized water;
3. The boiled fiber will be immediately drained and rinsed with cold deionized water;
4. A 2-liter volume of liquid will be taken from the loop;
5. The total fiber amount for the test is added to the removed loop liquid volume to form a suspension and held at 135 ± 5 °F;
6. The suspension will be agitated using a hand mixer (set at high speed) for four minutes;
7. The test engineer will visually examine the resulting slurry and insure that no clumps of wetted insulation exist;
8. Once the slurry agitation is complete, the suspension is agitated using a stirring rod;
9. Particulate is added to the fiber slurry and agitated using a stirring rod and visually examined to ensure no clumping of either debris type;
10. Agitation continues until slurry is added to the test loop.

The debris mixture is introduced into the column at the flanged opening above the screen. The debris slurry fiber-particulate mixture from the mixing container must be added slowly to the opening in the column over a period of one minute. The slurry mixture shall be poured slowly around the internal periphery of the opening to facilitate uniform bed thickness formation. While pouring the mixture, the slurry shall be agitated with a stirring rod in the container and in the column to ensure homogeneity of the mixture.

6.0 BASELINE TEST

A Baseline test will be performed with the appropriate fluid chemistry but without the insulation debris and potentially reactive materials which will provide non-chemical effects long term head loss across the test temperature range.

The best estimate water mass in containment for the design basis large break LOCA is 4,016,123 lb. with a volume of 64,360 ft^3 and 481,445 gallons at 70°F. This results in a test scaling factor of 750 gal / 481,445 gal = 0.001558.

6.1 Place Material in Reaction Chamber

The only material in the Reaction Chamber for the baseline test is the NaTB buffer.

1. Place 23.69 lbs of NaTB in the 6 buffer baskets.

6.2 Fill Test Loop

1. Align valves for the flow line-up shown in Figure 2.
2. Fill initial solution preparation chamber, vertical head loss loop, and heat exchanger loop with 750 gallons of deionized water.
3. Vent system and start P1 and P2.
4. Establish a flow rate of 6 gpm in both P1 and P2.

6.3 Establish Loop Chemistry

1. Add the appropriate quantity of boric acid and lithium hydroxide to establish the boron and lithium concentrations presented in Table 4.

Table 4: Chemistry Conditions

Deionized Water with	
Boron Concentration (H_3BO_3)	2800 ppm as boron
Lithium Hydroxide	0.78 ppm as lithium

2. Circulate the loop for 5 hours, approximately 5 complete fluid turn-overs.
3. Remove a 10 mL sample and check the pH.
4. Record the pH on the test data sheet.

6.4 Establish Debris Bed

1. Start the loop heater set for 135°F ± 5°F.
2. Obtain 16 grams of double-shredded NUKON insulation material and 80 grams of F600 Green silicon carbide.
3. Boil the NUKON in deionized water for 10 minutes.
4. Immediately drain the water and rinse the NUKON with cold deionized water.
5. After the loop temperature reaches 135°F ± 5°F remove a 2-liter volume of liquid from the loop.
6. Add the boiled and rinsed fiber to the removed loop liquid volume to form a suspension and hold at 135°F ± 5 °F.
7. Agitate the suspension using a hand mixer (set at high speed) for four minutes.
8. Visually examine the slurry and ensure that no clumps of wetted insulation exist
9. Add the silicon carbide to the fiber slurry and agitate using a stirring rod.
10. Visually observe to ensure no clumping of either debris type.
11. Agitation continues until slurry is added to the test loop.
12. Degas vertical head loss column.
13. Open the flanged cover at the top of the vertical head loss column.
14. Introduce the debris slurry fiber-particulate mixture slowly into the opening in the column over a period of one minute. The slurry mixture shall be poured slowly around the internal periphery of the opening to facilitate uniform bed thickness formation. While pouring the mixture, the slurry shall be agitated with a stirring rod in the container and in the column to ensure homogeneity of the mixture.
15. Close the flanged cover at the top of the vertical head loss column.
16. Set the loop heater for 195°F -0°F, +5°F

6.5 Fill Reaction Chamber

1. Once the loop temperature has stabilized at 195°F -0°F, +5°F, align the loop as shown in Figure 3.
2. After the initial solution chamber has emptied, align the loop as shown in Figure 4.
3. After a steady stream of fluid discharges from V5, align the loop as shown in Figure 5.
4. Replace any discharged fluid into the reaction chamber.
5. Verify that the debris bed ΔP has stabilized to less than 1% change per hour.
6. Reduce P1 flow rate to 1 gpm.

6.6 Run Experiment

1. Start P3
2. Establish flow rates of 6.0 gpm through V3 and 1.9 gpm through V4

The experiment will run for 744 hours (31 days). 24 hour around the clock monitoring is required for the first 5 days. The information on the Test Log (Attachment 1) shall be recorded no less than every 30 minutes during this period. Solution samples shall be taken daily and recorded on the Sample Log (Attachment 2). Photographs of the debris bed should be taken periodically.

For the next 25 days, the experiment will be monitored periodically on a daily basis. The information on the test data sheet shall be recorded no less than every 8 hours during this period. Solution samples shall be taken on Mondays, Wednesday, and Fridays.

Introduce Hydrochloric Acid (HCl) and Nitric Acid (HNO_3) in accordance with the schedule below. These quantities have been determined for a time dependent production rate based on bounding exposures: gamma and beta exposure in chlorine bearing insulation and gamma exposure in the containment sump pool.

Table 5: Strong Acid Concentration & Quantity Added

Concentration (mol/L)			Quantity Added (g)	
hours	**HCl**	**HNO_3**	**HCl**	**HNO_3**
0	0.00E+00	0	0	0
0.1	6.99E-07	7.19E-07	0.0724	0.1286
1	4.54E-06	5.26E-06	0.3976	0.8124
4	1.27E-05	1.49E-05	0.8447	1.7246
8	1.99E-05	2.33E-05	0.7453	1.5027
13	2.69E-05	3.16E-05	0.7246	1.4848
24	3.85E-05	4.55E-05	1.2008	2.4867
72	6.88E-05	8.13E-05	3.1365	6.4045
144	9.48E-05	1.13E-04	2.6914	5.6710
264	1.24E-04	1.50E-04	3.0226	6.6192
648	1.78E-04	2.10E-04	5.5898	10.7338
Note: Total in Solution			Note: Grams per addition	
Ref. 12				

On the final day, the experiment will be monitored continuously until completed. The information on the Test Log shall be recorded no less than every 30 minutes during this period. Solution samples shall be taken at the beginning of each temperature plateau and immediately before reducing temperature to the next plateau and recorded on the Sample Log.

7.0 DESIGN BASIS TEST

The Design Basis test will be performed with the appropriate fluid chemistry and the insulation debris and potentially reactive materials which will provide chemical effects long term head loss across the test temperature range.

7.1 Place Material in Reaction Chamber

The material in the Reaction Chamber for the baseline test includes the debris potentially generated from the HELB and potentially reactive materials in containment as shown below. These materials are presented as submerged in the containment pool or not submerged but exposed to containment spray.

Table 6: Fibrous Insulation Debris

Type	Destroyed (lb)	Scaled to Test (lb)	Submerged (lb)	Sprayed (lb)	Ref.
NUKON[1]	4921	7.67	3.38	4.29	10
Mineral Wool	467.4	0.73	0.73	0.00	10
Lead Blanket	72	0.11	0.11	0.00	10
Latent Fiber	22.5	0.04	0.04	0.00	10
Dirt & Dust	122.5	0.19	0.19	0.00	10

Table 7: Marinite Debris

Marinite	Destroyed (ft^3)	# 10 µm particles	Surface Area (ft^2)	Scaled (ft^2)	Ref.
Fines	0.19	1.03E+13	3.47E+04	54.1	11
Small + Large	0.47	N/A	11.3	0.02	11
Exposed to Spray	N/A	N/A	400	0.62	11

Table 8: Reactive Materials and Concrete

Metal	Surface Area (ft^2)	Scaled to Test (ft^2)	Submerged (ft^2)	Sprayed (ft^2)	Ref.
Aluminum	350	0.55	0.0	0.55	11
Galv Steel	95,000	148.0	14.8	133.2	9
Copper	150,000	233.7	23.4	210.3	9
Concrete	1000	1.56	0.2	1.4	9
Lead	400	0.62	0.62	0.0	6

[1] Surrogate for Thermal Wrap, Generic fiberglass, and Temp-Mat

Table 9: Qualified Coatings

Coating	Destroyed (ft^3)	# 10 μm particles	Surface Area (ft^2)	Scaled to Test (ft^2)	Ref.
IOZ	0.96606	5.22E+13	1.77E+05	275.2	8
Epoxy	1.44909	N/A	2898	4.5	8

Table 10: Degraded Qualified and Never Qualified Coatings

Coating	Surface Area (ft^2)	Scaled to Test (ft^2)	Submerged (ft^2)	Sprayed (ft^2)	Ref.
IOZ	6282	9.8	0.4	9.4	7
Epoxy	6282	9.8	0.4	9.4	7
Alkyd	7534	11.7	0.2	11.5	7

1. Place 3.38 lbs of NUKON insulation prepared in accordance with ¶5.1.1 in submerged fiber debris baskets.
2. Place 0.73 lbs of Mineral Wool insulation prepared in accordance with ¶5.1.1 in a submerged fiber debris basket.
3. Place 0.11 lbs of lead blanket jacket insulation prepared in accordance with ¶5.1.1 in a submerged fiber debris basket.
4. Place 0.04 lbs of latent fiber debris (NUKON) prepared in accordance with ¶5.1.1 in a submerged fiber debris basket.
5. Place 0.19 lbs of latent dirt and dust in a submerged debris basket.
6. Place 54.3 ft^2 of Marinite board prepared in accordance with ¶5.1.2 in submerged debris baskets.
7. Place 4.5 ft^2 of epoxy chips prepared in accordance with ¶5.1.3 in submerged debris baskets.
8. Place 4.29 lbs of NUKON insulation prepared in accordance with ¶5.1.1 in an unsubmerged fiber debris basket.
9. Place 0.62 ft^2 of Marinite board prepared in accordance with ¶5.1.2 in an unsubmerged debris basket.
10. Place 0.55 ft^2 of aluminum plates prepared in accordance with ¶5.1.4 in an unsubmerged coupon rack.
11. Place 14.8 ft^2 of galvanized steel plates prepared in accordance with ¶5.1.4 in a submerged coupon rack.
12. Place 23.4 ft^2 of copper plates prepared in accordance with ¶5.1.4 in a submerged coupon rack.
13. Place 0.2 ft^2 of concrete prepared in accordance with ¶5.1.2 in a submerged debris basket.
14. Place 0.62 ft^2 of lead prepared in accordance with ¶5.1.4 in a submerged debris basket.
15. Place 275.6 ft^2 of zinc plates prepared in accordance with ¶5.1.3 in a submerged coupon rack.

16. Place 0.4 ft^2 of epoxy coated plates prepared in accordance with ¶5.1.3 in a submerged coupon rack.
17. Place 0.26 ft^2 of alkyd coated plates prepared in accordance with ¶5.1.3 in a submerged coupon rack.
18. Place 133.2 ft^2 of galvanized steel plates prepared in accordance with ¶5.1.4 in an unsubmerged coupon rack.
19. Place 210.3 ft^2 of copper plates prepared in accordance with ¶5.1.4 in an unsubmerged coupon rack.
20. Place 1.4 ft^2 of concrete prepared in accordance with ¶5.1.2 in an unsubmerged debris basket.
21. Place 9.4 ft^2 of zinc plates prepared in accordance with ¶5.1.3 in an unsubmerged coupon rack.
22. Place 9.4 ft^2 of epoxy coated plates prepared in accordance with ¶5.1.3 in an unsubmerged coupon rack.
23. Place 11.5 ft^2 of alkyd coated plates prepared in accordance with ¶5.1.3 in an unsubmerged coupon rack.
24. Place 23.69 lbs of NaTB in the 6 buffer baskets.

7.2 Fill Test Loop

1. Align valves for the flow line-up shown in Figure 2.
2. Fill initial solution preparation chamber, vertical head loss loop, and heat exchanger loop with 750 gallons of deionized water.
3. Vent system and start P1 and P2.
4. Establish a flow rate of 6 gpm in both P1 and P2.

7.3 Establish Loop Chemistry

1. Add the appropriate quantity of boric acid and lithium hydroxide to establish the boron and lithium concentrations presented in Table 4.

Table 11: Chemistry Conditions

Deionized Water with	
Boron Concentration (H_3BO_3)	2800 ppm as boron
Lithium Hydroxide	0.78 ppm as lithium

2. Circulate the loop for 5 hours, approximately 5 complete fluid turn-overs.
3. Remove a 10 mL sample and check the pH.
4. Record the pH on the test data sheet.

7.4 Establish Debris Bed

1. Start the loop heater set for 135°F ± 5°F.
2. Obtain 16 grams of double-shredded NUKON insulation material and 80 grams of F600 Green silicon carbide.
3. Boil the NUKON in deionized water for 10 minutes.
4. Immediately drain the water and rinse the NUKON with cold deionized water.
5. After the loop temperature reaches 135°F ± 5°F remove a 2-liter volume of liquid from the loop.
6. Add the boiled and rinsed fiber to the removed loop liquid volume to form a suspension and hold at 135°F ± 5 °F.
7. Agitate the suspension using a hand mixer (set at high speed) for four minutes.
8. Visually examine the slurry and insure that no clumps of wetted insulation exist
9. Add the silicon carbide to the fiber slurry and agitate using a stirring rod.
10. Visually observe to ensure no clumping of either debris type.
11. Agitation continues until slurry is added to the test loop.
12. Degas vertical head loss column.
13. Open the flanged cover at the top of the vertical head loss column.
14. Introduce the debris slurry fiber-particulate mixture slowly into the opening in the column over a period of one minute. The slurry mixture shall be poured slowly around the internal periphery of the opening to facilitate uniform bed thickness formation. While pouring the mixture, the slurry shall be agitated with a stirring rod in the container and in the column to ensure homogeneity of the mixture.
15. Close the flanged cover at the top of the vertical head loss column.
16. Set the loop heater for 195°F -0°F, +5°F

7.5 Fill Reaction Chamber

1. Once the loop temperature has stabilized at 195°F -0°F, +5°F, align the loop as shown in Figure 3.
2. After the initial solution chamber has emptied, align the loop as shown in Figure 4.

7. After a steady stream of fluid discharges from V5, align the loop as shown in Figure 5.

3. Replace any discharged fluid into the reaction chamber.
4. Verify that the debris bed ΔP has stabilized to less than 1% change per hour.
5. Reduce P1 flow rate to 1 gpm.

7.6 Run Experiment

1. Start P3
2. Establish flow rates of 6.0 gpm through V3 and 1.9 gpm through V4

The experiment will run for 744 hours (31 days). 24 hour around the clock monitoring is required for the first 5 days. The information on the Test Log (Attachment 1) shall be recorded no less than every 30 minutes during this period. Solution samples shall be taken daily and recorded on the Sample Log (Attachment 2). Photographs of the debris bed should be taken periodically.

For the next 25 days, the experiment will be monitored periodically on a daily basis. The information on the test data sheet shall be recorded no less than every 8 hours during this period. Solution samples shall be taken on Mondays, Wednesday, and Fridays.

Introduce Hydrochloric Acid (HCl) and Nitric Acid (HNO_3) in accordance with the schedule below. These quantities have been determined for a time dependent production rate based on bounding exposures: gamma and beta exposure in chlorine bearing insulation and gamma exposure in the containment sump pool.

Table 12: Strong Acid Concentration & Quantity Added

Concentration (mol/L)			Quantity Added (g)	
hours	**HCl**	**HNO_3**	**HCl**	**HNO_3**
0	0.00E+00	0	0	0
0.1	6.99E-07	7.19E-07	0.0724	0.1286
1	4.54E-06	5.26E-06	0.3976	0.8124
4	1.27E-05	1.49E-05	0.8447	1.7246
8	1.99E-05	2.33E-05	0.7453	1.5027
13	2.69E-05	3.16E-05	0.7246	1.4848
24	3.85E-05	4.55E-05	1.2008	2.4867
72	6.88E-05	8.13E-05	3.1365	6.4045
144	9.48E-05	1.13E-04	2.6914	5.6710
264	1.24E-04	1.50E-04	3.0226	6.6192
648	1.78E-04	2.10E-04	5.5898	10.7338
Note: Total in Solution			Note: Grams per addition	
Ref. 12				

On the final day, the experiment will be monitored continuously until completed. The information on the Test Log shall be recorded no less than every 30 minutes during this period. Solution samples shall be taken at the beginning of each temperature plateau and immediately before reducing temperature to the next plateau and recorded on the Sample Log.

8.0 SAMPLE ANALYSIS

8.1 Corrosion Samples

The materials placed in the reaction chamber shall be photographed after the experiment. The materials shall be dried, weighed, placed in sealed containers and stored until a specific decision is made for disposal. The samples may be examined through scanning electron microscopy. Chemical analysis of the materials placed in the reaction chamber may be considered.

8.2 Sample Analysis

Chemical analysis of the fluid solution collected during each experiment and the material in the reaction tank may be performed. Mass spectrometry to determine the concentrations of the following elemental species should be considered:

1. Aluminum
2. Boron
3. Calcium
4. Chromium
5. Iron
6. Magnesium
7. Nickel
8. Molybdenum
9. Phosphorus
10. Silicon
11. Sulfur
12. Zinc

9.0 CHEMICAL EFFECTS HEAD LOSS

A chemical effects head loss is defined as any change in head loss not attributable to expected non-chemical effects reasons such as changes in fluid viscosity and density with changes in fluid temperature. Another potential increase in head loss not attributable to chemical effects is the gradual steady increase in debris bed head loss observed in most long term head loss tests. This is termed debris bed degradation. The cause of this gradual head loss increase is debris bed compaction and the subsequent decrease in porosity.

The debris bed head loss results from the Baseline Test (§6.0) and the Design Basis Test (§7.0) will be compared. Head loss differences between the tests will be analyzed and any increase in head loss than cannot be attributed to the reasons above will be deemed a chemical effects head loss.

A head loss variation of less than +10% compared to the baseline test after all head loss not attributable to expected non-chemical effects have been taken into consideration is considered negligible chemical effects head loss. If this is the result, chemical effects can be accounted for by adding a margin to the non-chemical effect strainer head loss results at CCNPP.

10.0 DEBRIS BED SENSITIVITY

As discussed earlier, CCNPP performed vertical loop head loss testing in late 2008 and early 2009 [Ref. 1] during which the detector debris bed was developed. A test was performed to demonstrate the sensitivity of the detector debris bed to chemical effects head loss. This test was performed at 135 °F using a screen approach velocity of 0.028 ft./sec. and 0.55 grams of sodium aluminum silicate chemical precipitate surrogate prepared according to the WCAP-16530 specifications added to the loop. This amount represented approximately 1-ppm of sodium aluminum silicate.

The debris bed differential pressure results of this test are shown in Figure 8. The differential pressure across the debris bed increased from approximately 0.2 ft-water to 8 ft-water. This is a 3900% increase in differential pressure due to the introduction of only 1-ppm of surrogate precipitate and clearly demonstrates the sensitivity of the detector debris bed.

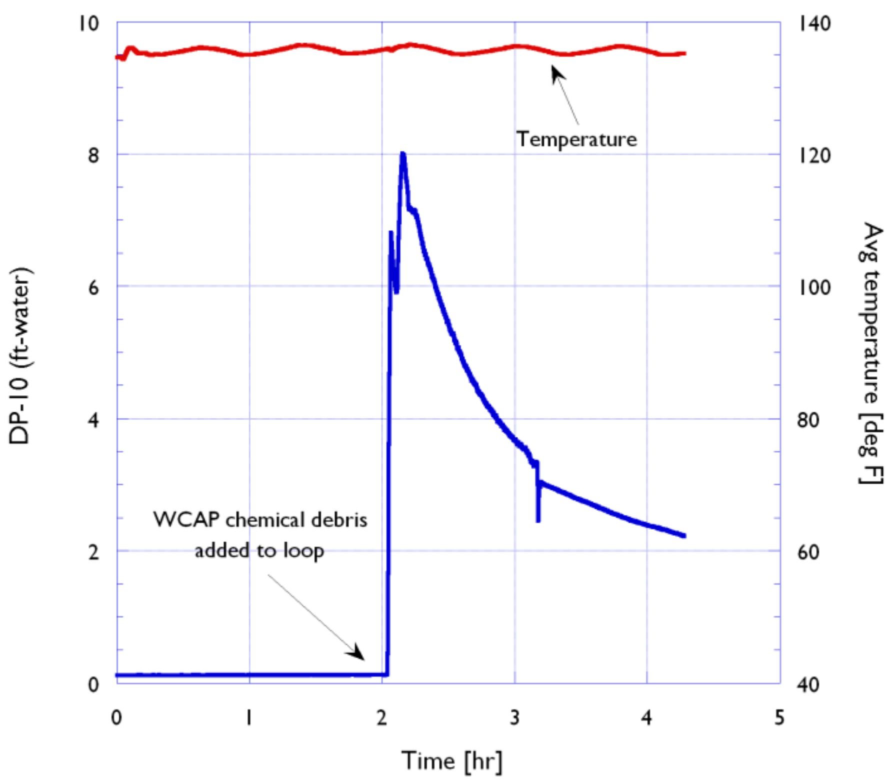


Figure 8: Debris Bed Differential Pressure

11.0 REFERENCES

1. Design Calculation CA07055, Rev. 0001 (ALION-REP-CCNPP-7311-001, CCNPP Chemical Effects Vertical Loop Head Loss Test Report, Revision 2).
2. "ZOI Fibrous Debris Preparation: Processing, Storage and Handling," Revision 0, Nuclear Energy Institute, October, 2011.
3. Design Calculation CA06774, Rev. 0002, Containment Response to LOCA and MSLB for Calvert Cliffs Units 1 and 2.
4. CCNPP Autoclave Test Report – CCNPP-CHLE-005
5. C. B. Bahn, K. E. Kasza, W. J. Shack, and K. Natesan, "Technical Letter Report on Evaluation of Long-term Aluminum Solubility in Borated Water Following a LOCA", ADAMS Accession No. ML081550043, U.S. Nuclear Regulatory Commission, Washington D.C., February 2008.
6. Design Calculation CA0xxxx, Rev. 000y, ENERCON Calculation No. CNSCC016-CALC-002, Calvert Cliffs Debris Generation Calculation.
7. Design Calculation CA06938, Rev. 0001, Prediction of LOCA Coating Debris Loads on the Containment Sump Strainer.
8. Design Calculation CA07464, Rev. 0000, Prediction of LOCA Coating Debris Loads on the Containment Sump Strainer.
9. Design Calculation CA0xxxx, Rev. 000y, ENERCON Calculation No. CNSCC016-CALC-004, Calvert Cliffs Containment Metal Calculation.
10. Design Calculation CA0xxxx, Rev. 000y, ENERCON Calculation No. CNSCC016-CALC-005, Calvert Cliffs Risk-Informed Debris Transport Calculation.
11. Design Calculation CA06940, Rev. 0001, Computation of Aluminum and Marinite Board Debris Load Inputs for Containment Sump Strainer.
12. Design Calculation CA0xxxx, Rev. 000y, MPR Calculation No. 0090-0269-01, Post-LOCA Time Dependent Radiolytic Production of Strong Acids.

Attachment 1

Test Log

Test Number: ________ Test Description: ____ Sheet# ______ of ________

Date	Time	Temperature				Flow Rate				Debris Bed		Turbidity		Comment
		T1	T2	T3	T4	F1	F2	F3	F4	ΔP	Thk	B1	B2	

Attachment 2

Sample Log

Test No: ______ Test Description: ______________________________ Sheet No.: ________ of: ______

Date	Time	Temp	Sample ID	Comment