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Constellation Energy
Nuclear Group

October 23, 2009

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-318
Supplemental Response to Generic Letter 2004-02

REFERENCES:

(a) Letter from Mr. J. A. Spina (CCNPP) to Document Control Desk (NRC), dated February 29, 2008, Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized Water Reactors"

(b) Letter from Mr. J. A. Spina (CCNPP) to Document Control Desk (NRC), dated September 30, 2008, Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized Water Reactors"

(c) Letter from Mr. J. A. Spina (CCNPP) to Document Control Desk (NRC), dated March 4, 2009, Request for Additional Information: Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized Water Reactors"

(d) Letter from Mr. J. A. Spina (CCNPP) to Document Control Desk (NRC), dated March 2, 2009, Additional Information re: Replacement of the Trisodium Phosphate Buffer with a Sodium Tetraborate Buffer

In Reference (a), Calvert Cliffs Nuclear Power Plant, Inc. submitted supplemental information as requested by the Nuclear Regulatory Commission (NRC) from all affected licensees. This letter described the status of our efforts at that time to address the concerns described in Generic Letter 2004-02. Additional Calvert Cliffs-specific testing occurred in the spring of 2008, along with plant modifications and additional calculations. The results of this additional effort were described in Revision 1 of our supplemental response (Reference b). In late fall 2008, further Calvert Cliffs-specific testing and evaluations were performed. Additional plant modifications were completed in the spring of

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2009. We have also provided information in response to a request for additional information in Reference (c) and discussed our use of both sodium tetraborate and trisodium phosphate buffer material in Containment in Reference (d).

Attachment (1) provides our final supplemental response. This response supersedes Reference (b). Changes from Reference (b) are marked with revision bars. Attachment (1) supplements information provided in Reference (c). Item 31 of Reference (c), along with the discussion in Reference (d), indicated that Unit 1 meets the design basis requirements of Generic Letter 2004-02 with a trisodium phosphate buffer material in the Unit 1 Containment. That conclusion relied on test results regarding the effect of temperature on head loss for aluminum-based chemical precipitates. These test results, and others, have been the topic of discussions with the NRC staff during the summer of 2009. These discussions have resulted in limitations on the use of temperature based head loss effects in our design basis evaluations. Therefore, we will change the buffer material on Unit 1 from trisodium phosphate to sodium tetraborate during the next Unit 1 refueling outage in the spring of 2010. This will increase our net positive suction head margin for the emergency core cooling pumps on Unit 1. This attached information supersedes our previous response to item 31 in Reference (c), since it was based on the use of trisodium phosphate buffer material. Other information in Reference (c) remains valid.

The NRC has also begun to challenge the conservative nature of industry testing to determine the zones of influence of water impingement on certain types of insulation found in reactor containments. We, like a number of other plants, have relied upon the NRC-approved topical reports which describe the testing and have used the results in our own testing and evaluations. The attached supplemental response describes our testing and evaluations assuming that the approved topical reports still form an acceptable basis for these actions. However, we are also evaluating the impact of this potential revised NRC position on our past test results and our evaluations of potential debris generation. Preliminary scoping studies indicate an acceptable outcome without additional testing and within the conservative constraints that may be required by the NRC staff. Once the NRC staff establishes an acceptable approach to determining an appropriate zone of influence for certain types of insulation, we will re-evaluate our response. At this time, no plant modifications or testing appear to be required to address this issue.

Should you have questions regarding this matter, please contact Mr. Jay S. Gaines at (410) 495-5219.

Very truly yours,

James A. Spina

STATE OF MARYLAND :
: **TO WIT:**
COUNTY OF CALVERT :

I, James A. Spina, being duly sworn, state that I am Vice President-CNG Corporate Site Operations, and that I am duly authorized to execute and file this response on behalf of Calvert Cliffs Nuclear Power Plant, Inc. (CCNPP). To the best of my knowledge and belief, the statements contained in this document are true and correct. To the extent that these statements are not based on my personal knowledge, they are based upon information provided by other CCNPP employees and/or consultants. Such information has been reviewed in accordance with company practice and I believe it to be reliable.

James A. Spina

Subscribed and sworn before me, a Notary Public in and for the State of Maryland and County of St. Mary's, this 23RD day of October, 2009.

JANET L. SCULLY NOTARY PUBLIC SAINT MARY'S COUNTY, MD

WITNESS my Hand and Notarial Seal:

Janet L. Scully
Notary Public

My Commission Expires:

March 1, 2011
Date

JAS/PSF/bjd

Attachments: (1) Supplemental Response to Generic Letter 2004-02
Enclosure: (1) Aluminum Precipitate Head Loss Considerations
(2) ECCS and CS System Figures

cc: D. V. Pickett, NRC
S. J. Collins, NRC
Resident Inspector, NRC
S. Gray, DNR

ATTACHMENT (1)

SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02

OVERALL COMPLIANCE

NRC Issue 1:

Provide information requested in GL 2004-02, "Requested Information." Item 2(a) regarding compliance with regulations. That is, provide confirmation that the ECCS and CSS recirculation functions under debris loading conditions are or will be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. This submittal should address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made and this licensing basis has been updated to reflect the results of the analysis described above.

Response to Issue 1:

At Calvert Cliffs, an emergency recirculation sump is provided for each unit. Each Emergency Core Cooling System (ECCS) sump serves both trains of the ECCS and the Containment Spray (CS) system. In response to the Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02, Calvert Cliffs Nuclear Power Plant has significantly modified the containment ECCS sump strainer with a passive strainer system designed, manufactured and tested by Control Components, Incorporated (CCI) of Winterthur, Switzerland. This system has a strainer surface area of approximately 6,000 ft^2. The sump strainer system ensures the NPSH available exceeds the pump requirements following a loss-of-coolant accident (LOCA), thereby not impacting the operability of the ECCS and CS system.

The containment sump strainer system was installed in Unit 2 during the spring 2007 refueling outage and in Unit 1 during the spring 2008 refueling outage. The system has three strainer module rows utilizing 33 strainer modules connected to a central water duct that discharges directly into the sump, which houses the two ECCS pump suction lines. Each strainer module has a series of strainer cartridges constructed of perforated stainless steel plate. Following a LOCA event, all liquid used for recirculation must pass through these strainer cartridge perforations or similar sized strainer system gaps prior to entering the sump. The strainer in the Containment is sized for the expected design basis debris load. Structural upgrades were performed on the Unit 2 sump in 2009 to provide additional strength. Similar structural upgrades will be completed for Unit 1 during the 2010 refueling outage.

Tests, evaluations, and calculations have been performed to demonstrate that the new strainers provide adequate debris removal and sufficiently low head loss during recirculation that adequate NPSH is provided to the pumps of the ECCS and CS system.

The sump strainer system installed at Calvert Cliffs provides sufficient strainer capability during recirculation to allow the ECCS systems to perform their required function of cooling the nuclear core and maintaining its temperature acceptably low enough for the extended period required by the long lived radioactivity remaining in the core. Furthermore, the containment spray system also is provided with sufficient flow during recirculation such that adequate containment heat removal and atmosphere clean-up is provided. Calvert Cliffs is in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of Generic Letter 2004-02 except for the remaining actions noted in the Response to Issue 2.

The Calvert Cliffs licensing basis will be updated in accordance with the requirements of 10 CFR 50.71 to reflect the results of the analyses and the modifications performed to demonstrate compliance with the regulatory requirements. A license amendment has been approved to change the containment buffer material from trisodium phosphate to sodium tetraborate (Reference 30). The buffer material change reduces the chemical effects on the strainers by eliminating the calcium phosphate precipitate, thereby reducing the assumed head loss across the strainer and debris bed and increasing NPSH margin. The buffer material change was completed during the refueling outage in 2009 for Unit 2 and will be completed during the refueling outage in 2010 for Unit 1.

The responses that follow present a number of conservatisms. They are summarized below:

- Use of Reference 22 (WCAP-16530-NP-A) to determine the quantity of chemical precipitates.
- No temperature corrections to head loss based on viscosity variations dependent on temperature.
- Use of head loss due to full debris load without chemical effects at the start of recirculation in NPSH margin calculations.
- Inclusion of chemical effects head loss at a temperature below 140°F, when Calvert Cliffs-specific tests show no chemical effects for temperatures as low as 65°F.
- Inclusion of head loss conservatively predicted due to use of surrogate chemical precipitate.
- Use of the assumption that all debris fines transport to the strainer when tests clearly required significant and non-prototypical agitation to force such transport.
- Use of the Reference 10 transport fractions for debris. Much of Containment has low flow conditions or is entirely quiescent. Debris that is transported to those regions in the initial post-LOCA period would not be expected to transport away again. No credit is taken for this effect.
- The minimum pool level does not credit any lower containment equipment displacing water. It credits only the volume of the concrete pedestals.
- No credit is taken for RCS fluid volume in the minimum pool level. For a LBLOCA especially, this is quite conservative.
- No containment accident pressure is credited beyond that required to maintain the pressure consistent with the sump fluid temperature at or above saturation conditions of 212°F.
- Bounding debris quantities from each of the break locations were used in head loss testing and wear analyses.
- Assumption of the latent debris quantity based on the larger quantity from the two units.
- Wear analyses assumed no hold-up of particulate in various locations: the fiber bed, the reactor vessel, and the refueling canals and reactor cavity.
- Very large strainer with resultant low strainer flow.
- Assume all coating debris fails at time of accident.
- Latent debris was assumed to all be particulate.
- Assume no depletion of particulates over 30 days.

GENERAL DESCRIPTION OF AND SCHEDULE FOR CORRECTIVE ACTIONS

***NRC Issue 2*:**

Provide a general description of actions taken or planned, and dates for each. For actions planned beyond December 31, 2007, reference approved extension requests or explain how regulatory requirements will be met as per "Requested Information" Item 2(b). That is provide a general description of and implementation schedule for all corrective actions, including any plant modifications, that you identified while responding to this generic letter. Efforts to implement the identified actions should be initiated no later than the first refueling outage starting after April 1, 2006. All actions should be completed by December 31, 2007. Provide justification for not implementing the identified actions during the first refueling outage starting after April 1, 2006. If all corrective actions will not be completed by December 31, 2007, describe how the regulatory requirements discussed in the Applicable Regulatory Requirements section will be met until the corrective actions are completed.

Response to Issue 2:

As of September 30, 2009, Calvert Cliffs Units 1 and 2 have completed the following GL 2004-02 actions, analyses and modifications.

- Latent debris walkdowns
- Debris generation analysis
- Insulation debris calculation (including RMI transport)
- Containment debris transport analysis
- Hydraulic model of the ECCS
- Head loss analysis
- Bypass testing
- Vortex testing and analysis
- Head loss testing for the strainer (including chemical effects with the replacement buffer)
- Calvert Cliffs-specific chemical solubility and precipitation testing
- High pressure safety injection (HPSI) cyclone separator blockage testing
- Detailed structural analysis of the new strainers
- Installed 6000 ft^2 surface area replacement strainer system in Units 1 and 2
- Calcium-silicate pipe insulation removal or banding within the zone of influence
- HPSI cyclone separator replacement
- Aluminum abatement
- Containment sump buffer material replacement for Unit 2
- Completed calculations addressing:
  - Downstream effects on static components
  - Downstream effects on pumps
  - Strainer vendor head loss testing report
  - Strainer vendor head loss and vortexing calculation
  - NPSH margin calculation
  - Chemical effects and precipitation calculation
  - Minimum sump pool depth

Generic Letter 2004-02 actions remaining are:

- Calvert Cliffs Units 1 and 2 have requested (Reference 24) and received approval for (Reference 25) an extension until 90 days after the NRC issues its safety evaluation WCAP-16793-NP to complete in-vessel downstream effects calculations.
- Modification of the Unit 1 sump during the 2010 RFO to improve structural strength. The modification adds additional support legs to the three cross beams located inside the original sump pit.
- Containment sump buffer material replacement for Unit 1.
- Remove insulation from two pipes in Unit 1 during the 2010 RFO to improve margin. The two pipes are the shutdown cooling line insulated with encapsulated mineral wool insulation, and the pressurizer relief valve line outside of the pressurizer compartment insulated with generic fiberglass insulation.
- Remove debris interceptors from Unit 1.
- Add blowout panels to reactor cavity cooling ducts for Unit 1 and Unit 2.

The following tests were presented in the February 2008 supplemental response. Subsequent analyses have shown that these tests are no longer necessary. Calvert Cliffs no longer intends to perform them.

- ECCS throttle valve wear and blockage testing
- CS and HPSI pump mechanical seal testing
- Debris interceptor testing

SPECIFIC INFORMATION REGARDING METHODOLOGY FOR DEMONSTRATING COMPLIANCE

NRC Issue 3a:

Break Selection

The objective of the break selection process is to identify the break size and location that present the greatest challenge to post-accident sump performance.

1. *Describe and provide the basis for the break selection criteria used in the evaluation.*
2. *State whether secondary line breaks were considered in the evaluation (e.g., main steam and feedwater lines) and briefly explain why or why not.*
3. *Discuss the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance.*

*Response to Issue 3a*1:

A number of breaks were considered to ensure that the breaks that bound variations in debris generation by the size, quantity, and type of debris are identified. The selection of line break locations evaluated depends on both maximizing debris generation, and maximizing debris types which might create the worst-case debris mixture for strainer head loss.

The reactor cavity wall and bio-shield walls of the containment interiors divide the RCS piping into two completely separate compartments which are closed at the top and sides, and partially closed at the bottom. The compartment size is such that a break in the hot leg (42" ID) can adversely affect all the non-encapsulated insulation inside the compartment in which it is located. Therefore, the maximum insulation debris is generated by a hot leg break (which is larger than a cold leg break) located at the base of the steam generator (largest source of insulation).

For insulation, each compartment was evaluated for this hot leg break to determine which compartment would result in the worst debris mix for the strainer design. This evaluation computed the volumes of each insulation debris source that was generated, and then converted this to a mass using the applicable density. The compartment having the highest mass of insulation debris was used for the fiber load. The chemical precipitate prediction used the quantity of insulation from the compartment in which the largest mass of fiberglass insulation debris was generated and the compartment in which the largest mass of mineral wool insulation debris was generated. The coating debris load considered cold leg breaks as well, since some of the cold legs were routed near large amounts of coated structural steel. The pipe break having the highest coating debris load was not the same as the pipe break having the highest insulation mass load. Therefore, the bounding debris load used in head loss testing and wear evaluations, etc., utilized the results from the break generating the most insulation debris and the break generating the most coatings debris. The results of debris generated in each compartment are in Response to Issue 3b4.

Breaks in other parts of the RCS hot leg would generate less steam generator insulation debris. Breaks in the RCS cold leg and surge lines will generate the same types of insulation debris in smaller quantities.

A break in the reactor cavity (inside the primary shield wall) only generates reflective metal insulation debris, and thus will have much smaller impact on strainer head loss.

Response to Issue 3a2:

For feedwater line breaks and main steam line breaks, recirculation from the ECCS sump is not credited for the accident response for Calvert Cliffs. Therefore, analysis of breaks in the main steam and feedwater lines were not performed.

Response to Issue 3a3:

Based on the above discussion, the break selection included the location with the greatest effect on insulation, has the most direct path to the ECCS sump, and generated the largest amount of coating debris. These three effects of the postulated break produce the greatest debris at the strainer including debris that may bypass the strainer and produce adverse downstream effects. Therefore, the hot leg break in the 12/22 Steam Generator compartment is currently considered to be the biggest challenge to post-accident sump performance.

***NRC Issue 3b*:**

Debris Generation/Zone of Influence (zone of influence) (excluding coatings)

The objective of the debris generation/zone of influence process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; and (2) the amount of debris generated by the break jet forces.

1. *Describe the methodology used to determine the zone of influences for generating debris. Identify which debris analyses used approved methodology default values. For debris with zone of influences not defined in the guidance report (GR)/safety evaluation (SE), or if using other than default values, discuss method(s) used to determine zone of influence and the basis for each.*
2. *Provide destruction zone of influences and the basis for the zone of influences for each applicable debris constituent.*
3. *Identify if destruction testing was conducted to determine zone of influences. If such testing has not been previously submitted to the NRC for review or information, describe the test procedure and results with reference to the test report(s).*
4. *Provide the quantity of each debris type generated for each break location evaluated. If more than four break locations were evaluated, provide data only for the four most limiting locations.*
5. *Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in Containment.*

Response to Issues 3b1 and 3b2:

Calvert Cliffs insulation systems are representative of the materials tested in References 5 to 8 except for Transco reflective metal insulation, generic fiberglass insulation, and Temp Mat insulation. The zones of influence for these three systems follow the guidance of Reference 10.

Table 3b1-1
Summary of Containment Materials Zones-of-Influence

Material	Zone of Influence Radius Break Diameter	Reference
Transco reflective metal insulation	2 & 7	Reference 10, Volume 2, page 30
Transco mineral wool	7	Note 1
Nukon jacketed w/standard bands	7	Reference 5, page 1-6 (Note 2)
Transco Thermal Wrap	7	Note 3
Calcium-silicate insulation	3	Reference 6, page 1-4 (Note 4)
Generic fiberglass insulation	17	Note 5
Temp-Mat insulation	11.7	Reference 10, Table 3-2 (Note 6)
Inorganic zinc coatings without topcoat	5	Reference 7, page 1-2
Epoxy coatings	4	Reference 7, page 1-3
Marinite board	9.8	Reference 8, page 4-3 and Calvert Cliffs-specific evaluation

Note 1: The mineral wool at Calvert Cliffs was procured from Transco using the same specification as the Transco reflective metal insulation. Both insulations are encapsulated in an identical manner. Use of a relatively small zone of influence in this application is corroborated by the work done in Reference 5 for encapsulated Min-K insulation where a small zone of influence was also observed and is substantiated by an engineering evaluation of the Calvert Cliffs encapsulated mineral wool insulation system.

Note 2: Reference 5 actually justifies a zone of influence of 5 L/D; however, for conservatism the document recommends a zone of influence of 7 L/D.

Note 3: Transco Thermal Wrap is a low-density fiberglass insulation nearly identical to Nukon, and is jacketed in a nearly identical manner. Therefore, the same zone of influence is applied.

Note 4: Use of the specified zone of influence assumes that jacketing is banded at 3" centers. All calcium-silicate insulation with the potential of being in a zone of influence has been banded at 2 ¾" centers up to the third elbow, and at 6" centers past the third elbow.

Note 5: Our generic fiberglass insulation, while a low-density fiberglass, does not have the cloth jacketing of Nukon or thermal wrap, and its jacketing is of a thinner gauge and is held on by rivets, not bands. At present, the conservative zone of influence for unjacketed Nukon from page 30 of Reference 10 is applied.

Note 6: Temp-Mat is a heavier insulation than Nukon, and per Table 3-2 of Reference 10 it has a zone of influence of 11.7 when a stainless steel wire retainer is used.

Response to Issue 3b3:

Destructive testing was used to determine the zones of influence of the Nukon, calcium-silicate, zinc primer, epoxy, and Marinite board. Documentation of this testing is provided in References 5 through 8. An engineering evaluation was used to address Transco mineral wool and its zone-of-influence which examined the encapsulation relative to the jacketed NUKON tested in the work reported in Reference 5. A summary description of the test procedure and results is provided below.

The following description applies to all of the WCAP testing:

Testing was conducted at Wyle Labs. The jet model described in American National Standards Institute/American Nuclear Society Standard 58.2-1988 was used to evaluate the placement of test articles in front of the jet nozzle. A two-phase jet originating from a sub-cooled, high pressure, high temperature reservoir was directed at the test articles. A rupture disk was used to simulate a pipe break. This is a similar approach as that taken by the NRC for testing reported in Appendix VI.3.2.2 of Reference 10, and by others as reported in Section 3.2.2 of Reference 9.

WCAP-16710-P (Reference 5): The test article consisted of jacketed Nukon fiber wrapped around an 8" schedule 80 pipe. At a zone of influence of 5 diameters (D) no damage to the Nukon pillow was observed beyond that attributed to the impact and abrasion of the test fixture.

WCAP-16720-P (Reference 6): The test article consisted of jacketed calcium-silicate insulation banded at 3" centers mounted on a 2" schedule 160 pipe. At a zone of influence of 3D, the stainless steel jacketing was bent and torn between the clamps and the calcium-silicate insulation appeared intact along the length of the specimen.

WCAP-16568-P (Reference 7): The test articles of interest to Calvert Cliffs included non-topcoated inorganic zinc primer on a steel substrate and inorganic zinc primer with two coats of epoxy topcoat on a steel substrate. For epoxy-based coatings regardless of the substrate to which they were applied, no detectible coating loss was determined at the tested length/diameters (L/D) of 2.06 and 1.37. The non-topcoated inorganic zinc primer showed some loss of coating thickness at an L/D = 3.23, and less at an L/D = 3.68. Extrapolation determined that no coating loss would occur at an L/D of 4.28.

SL-009195 (Reference 8): Testing was conducted at Wyle Labs using their hot water blowdown test facility. The test article consisted of ½" Marinite board attached to 16-gauge galvanized steel cable tray sections. At zones of influence less than 8.0 L/D, erosion was observed at the point of jet impingement. The maximum specimen weight-loss was found to be 0.87%.

Response to Issue 3b4:

The following table presents the debris generated for postulated breaks located in the listed compartments.

Table 3b4-1
Summary of LOCA Generated Debris

Debris Name	Debris Type	11 Compartment Volume (ft^3)	12 Compartment Volume (ft^3)	21 Compartment Volume (ft^3)	22 Compartment Volume (ft^3)	Bounding Volume (ft^3)
Mineral wool insulation	Fiber	64.95	170	50.25	91.92	170
Generic fiberglass	Fiber	215.63	102.22	63.45	52.57	215.63
Temp-Mat insulation	Fiber	19.55	29.58	18.11	33.07	33.07
Transco Thermal Wrap insulation	Fiber	476.80	475.63	471.58	478.35	478.35
Nukon insulation	Fiber	392.29	321.30	390.13	334.82	392.29
Transco reflective metal insulation (Note 4)	Metal	N/A	N/A	N/A	N/A	0.825
Qualified coatings	Particulate	N/A (Note 2)	1.45	N/A (Note 2)	N/A (Note 2)	1.45
Unqualified coatings, Alkyds	Particulate	1.30	1.30	1.30	1.30	1.30
Latent debris	Particulate (Note 5)	1.5	1.5	1.5	1.5	1.5

Debris Name	Debris Type	11 Compartment Volume (ft^3)	12 Compartment Volume (ft^3)	21 Compartment Volume (ft^3)	22 Compartment Volume (ft^3)	Bounding Volume (ft^3)
Qualified Inorganic Zinc Primer	Particulate	0.713	0.966	N/A (Note 1)	N/A (Note 1)	0.966
Unqualified coatings, Inorganic Zinc Primer	Particulate	3.83	3.83	3.83	3.83	3.83
Marinite Board	Total	0.062	0.104	0.085	0.092	0.104
Marinite Board	Fiber (Note 3)	0.005	0.008	0.007	0.007	0.008
Marinite Board	Particulate (Note 3)	0.057	0.096	0.078	0.085	0.096

Note 1: Unit 2 Inorganic zinc primer quantities are assumed equal to those of Unit 1.

Note 2: Coatings debris for Compartment 11, 21, and 22 breaks were not explicitly presented in the design calculation.

Note 3: Marinite board is about 8% fiber and 92% particulate according to the manufacturer's data sheets. The board is assumed to fail in similar proportions during the LOCA event.

Note 4: The bounding RMI break is located in the reactor cavity. The foil of the Calvert Cliffs insulation is 0.002 inches thick and the area of foil destroyed is about 5,000 ft^2.

Note 5: Latent debris is assumed to be 100 lb/ft^3.

Response to Issue 3b5:

The strainer design allows for 375 ft^2 of sacrificial surface area. This was to account for the stick-on type labels applied to items such as cable trays. Additional walkdowns were performed in the spring 2009 refueling outage to ensure that labels and tags plus insulation types were completely investigated. The area of labels were identified and found to be significantly less than the sacrificial area assumed in the design. Valve tag labels are made of materials that will sink intact. Procedures require that all placards be chained so they won't transport to the sump strainer.

NRC Issue 3c:

Debris Characteristics

The objective of the debris characteristics determination process is to establish a conservative debris characteristics profile for use in determining the transportability of debris and its contribution to head loss.

1. *Provide the assumed size distribution for each type of debris.*
2. *Provide bulk densities (i.e., including voids between the fibers/particles) and material densities (i.e., the density of the microscopic fibers/particles themselves) for fibrous and particulate debris.*
3. *Provide assumed specific surface areas for fibrous and particulate debris.*
4. *Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.*

Response to Issue 3c1:

The debris sources at Calvert Cliffs include insulation, coating, and latent debris. Calvert Cliffs uses the guidance provided by NEI in Reference 10 to determine the size distribution for debris. This results in the following assumptions:

- 60% of the destroyed NUKON, Thermal Wrap, and Temp-Mat insulation are considered fines and transportable. The remainder are large pieces and are not considered to be transportable in the lower Containment.
- 100% of the destroyed mineral wool and generic fiberglass insulation are considered fines and are transportable.

Table 3c1-1 provides the debris size distribution assumed for the different types of debris.

Test procedures used at CCI in the fall of 2008 reduced insulation to fines, which are introduced into the test flume. Bounding quantities of insulation were used in head loss testing (see Response to Issue 3b4). Therefore, conservative quantity of insulation fines were used in head loss testing, including chemical effects head loss testing.

All particulate debris (coatings, latent dust and dirt, and Marinite board) are assumed to be fully transportable. Bounding masses of particulate were selected when test materials were identical to plant materials. The test flume was carefully agitated to ensure that all materials were transported without disturbing the debris bed.

Table 3c1-1
Debris Size Distribution

Material	Percentage Small Fines	Percentage Large Pieces
Nukon insulation	60	40
Transco Thermal Wrap insulation	60	40
Temp-Mat insulation	60	40
Generic fiberglass	100	0
Mineral wool	100	0
Fire barrier in zone of influence	see Note 1	0
Coatings in zone of influence	100 (<10 μm)	0
Qualified coatings outside zone of influence	0	0
Unqualified coatings outside zone of influence	see Response to Issue 3c4	see Response to Issue 3c4
Fire barrier (covered) outside zone of influence	0	0
Fire barrier (uncovered) outside zone of influence	0	0
Latent debris	100 (<10 μm)	0

Note 1: Calvert Cliffs uses Marinite board as a fire barrier material for cable trays. The quantity of destroyed Marinite is considered fully transportable. A maximum of 56 ft^2 of half inch thick Marinite board produces a total of 0.104 ft^3 of debris, of which only about 0.042 ft^3 are fines or small pieces and therefore would transport to the sump strainer.

Response to Issue 3c2:

The bulk densities of material and destroyed debris are listed in the table below. These values are obtained from the NRC-approved methodology or vendor specific information (in the case of coatings).

Table 3c2-1
Debris Densities

Insulation Type	Density of Individual Fiber (lb_m/ft^3)	Density of a Blanket of Product (lb_m/ft^3)
Nukon	159	2.4
Transco Thermal Wrap	159	2.4
Generic fiberglass	159	5.5
Temp-Mat	162	11.8
Mineral wool	90	8

Coating Material	Material Density (lb_m/ft^3)	Characteristic Size (ft)
Inorganic zinc	457	$3.2x10^{-5}$
Alkyd coating	98	$3.2x10^{-5}$

Topcoats

Vendor	Trade Name	Dry Film Density (lb/gal)	Dry Film Density (lb/ft^3)
Carboline	Carboguard 890	14.52	109
Ameron	Amercoat 66	14.04	105
Ameron	Amercoat 90	14.80	111
Valspar	89 Series	14.04	105

Primers

Vendor	Trade Name	Dry Film Density (lb/gal)	Dry Film Density (lb/ft^3)
Carboline	Carboguard 890	14.52	109
Carboline	Starglaze 2011 S	19.28	144
Ameron	Dimetcote 6	40.1	300
Ameron	Nu-Klad 110AA	20.1	150
Valspar	13-F-12	40.1	300

From Section 3.5.2.3 of Reference 10 the following properties are to be used for latent debris: (Note that latent debris was assumed to be all particulate. No fibers were observed in latent debris sampling and any fibers assumed would add an insignificant fiber load to the debris noted in Response to Issue 3b4 above.)

Particulate density = 100 lb_m/ft^3
Particulate diameter = 10 μm ($3.28x10^{-5}$ ft)

Response to Issue 3c3:

Since the head loss across the ECCS strainers is determined via testing, specific surface areas for fiberous and particulate debris are not used to determine debris transportability. Therefore, these values are not provided as part of this response.

Response to Issue 3c4:

The Calvert Cliffs debris generation, transport, and head loss analyses have used the debris characterization assumptions provided in Reference 10, Volumes 1 and 2. Specifically, the size of particulates is consistent with 10 microns for coatings particulate. Coatings that were installed as qualified, but have been subsequently classified as unqualified based on inspections are assumed to have failure distributions consistent with that reported in Reference 11. In general, Reference 11 concludes that epoxy topcoated systems fail as chips when exposed to design basis accident environments, while non-topcoated inorganic zinc primers fail in pigment size (i.e., 10 microns). For downstream effect evaluations, the size distribution of unqualified coatings was assumed to be that given in the Linear Mass Fraction column of Table I-1 of Reference 12.

NRC Issue 3d:

Latent Debris

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris existing within the Containment and its potential impact on sump screen head loss.

1. *Provide the methodology used to estimate quantity and composition of latent debris.*
2. *Provide the basis for assumptions used in the evaluation.*
3. *Provide results of the latent debris evaluation, including amount of latent debris types and physical data for latent debris as requested for other debris under c. above.*
4. *Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris.*

Response to Issue 3d1:

The Containment was sampled via a walkdown performed to collect latent debris samples from the various surfaces in Containment. The surface types sampled included: 1) containment liner, 2) floor, 3) stair grating, 4) walls, 5) horizontal cable trays, 6) vertical cable trays, 7) horizontal piping, 8) vertical piping, 9) horizontal ducting, 10) vertical ducting, 11) horizontal equipment, and 12) vertical equipment. A minimum of four samples were taken from each surface type. The area of each sample was recorded along with the weight of latent debris in the sample area. The average and maximum weight per unit surface area were recorded. The averages were then multiplied by the horizontal and vertical surface areas that might have latent debris accumulate on them which resulted in the latent debris loading for Containment. The latent debris load results used the maximum sample for each surface type with the exception of the grating of stairs where it was determined that a non-representative sample existed.

Response to Issue 3d2:

Debris was assumed to be normally distributed for a given sample type. This assumption was supported by the walkdown observation that latent debris was uniform for a given surface type. Averaging the latent debris for surface types having multiple samples is consistent with the sampling approach taken to estimate the amount of latent debris inside Containment.

Response to Issue 3d3:

Latent debris includes dirt, dust, lint, fibers, etc., that are present inside the Containment and could be transported to the ECCS sump screen during the post-LOCA recirculation phase of ECCS operation. This debris could be a contributor to head loss across the ECCS sump screen. In accordance with recommendations in Reference 13, latent debris samples were collected to estimate the actual mass of latent debris inside of Containment. A latent debris load of 150 lbs was computed. The latent debris was described as dust with no fiber in any sample.

Response to Issue 3d4:

Latent debris (in the form of dust) is accounted for in test and analysis by including it in the debris mix. Therefore, no specific sacrificial area needs to be allocated to it. Foreign material such as paper inadvertently left inside Containment is accounted for by crediting the foreign material exclusion programmatic methods described in the Response to Issue 3i3 below. Therefore, Calvert Cliffs does not provide an amount of sacrificial strainer surface area allotted to miscellaneous latent debris other than that allocated for stick-on labels (see Response to Issue 3b5 above).

NRC Issue 3e:

Debris Transport

The objective of the debris transport evaluation process is to estimate the fraction of debris that would be transported from debris sources within Containment to the sump suction strainers.

1. *Describe the methodology used to analyze debris transport during the blowdown, washdown, pool-fill-up, and recirculation phases of an accident.*
2. *Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance.*
3. *Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results.*
4. *Provide a summary of, and supporting basis for, any credit taken for debris interceptors.*
5. *State whether fine debris was assumed to settle and provide basis for any settling credited.*
6. *Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers.*

Response to Issue 3e1:

Calvert Cliffs uses the size distribution for fiber and particulates provided in Table 3-3 of Reference 10 and assumed that all small fines transport to the sump strainer.

For previously qualified coatings outside the zone of influence, credit is taken for the non-transportability of the coating chips at velocities less than 0.2 ft/sec as allowed by Reference 14. Calvert Cliffs used the same velocity to determine the non-transportability of reflective metal insulation (RMI) foil fragments.

Coating chips were tested for transportability at up to 8 times nominal flow through the strainer with no transportability found at that flow. The head loss calculations examined flows through a clean strainer and found spatial variations of flow speed up to 6.7 times nominal. Therefore, the transportability of coatings chips was determined to be negligible for the flows near the sump strainer. RMI foil fragments have greater density than the coatings and thus a greater propensity to sink and remain immobile. Therefore, the transportability of the coatings bounds the transportability of the RMI foil fragments.

Response to Issue 3e2:

There were no deviations from approved guidance (References 10 and 14) regarding debris transport.

Response to Issue 3e3:

No computational fluid dynamics codes were used by Calvert Cliffs.

Response to Issue 3e4:

Calvert Cliffs installed debris interceptors in Unit 1 during the spring 2008 refueling outage to shield a portion of the strainer surface area from debris. No credit is taken in evaluations for these debris interceptors. No similar debris interceptor is installed in Unit 2. The debris interceptor in Unit 1 is planned for removal in the 2010 refueling outage.

Response to Issue 3e5:

Calvert Cliffs did not credit the settling of small debris fines in the transport calculations.

Response to Issue 3e6:

Table 3e6-1
Bounding Debris Quantity at ECCS Sump Screen for Calvert Cliffs

Debris Name	Quantity Generated (ft^3)	Transport Fraction	Quantity at Sump (ft^3)
Fibrous debris			
- Nukon	392.29	0.60	235.37
- Transco	478.35	0.60	287.01
- Temp-Mat	33.07	0.60	19.84
- Generic	215.63	1.00	215.63
- Mineral wool	170	1.00	170
		TOTAL	927.85
Transco reflective metal insulation debris (RMI foil 0.002" thick)	0.825	0 (Note 1)	0
Qualified coatings	2.415	1.00	2.415
Unqualified coatings	5.13	1.00	5.13
Latent debris	1.5	1.00	1.5
Marinite board particulate Note 2	0.104	1.00	0.104
		TOTAL	9.149

Note 1: Calvert Cliffs has determined that the flow speed in the recirculation pool in lower Containment is inadequate to suspend and transport RMI foil to the strainer. See the Response to Issue 3e1 above.

Note 2: Calvert Cliffs assumed all Marinite board debris to be particulate. The minor additional fiber that is present in the Marinite board debris would have undetectable effects in the high fiber loading seen in Table 3e6-1.

***NRC Issue 3f*:**

Head Loss and Vortexing

The objectives of the head loss and vortexing evaluations are to calculate head loss across the sump strainer and to evaluate the susceptibility of the strainer to vortex formation.

1. *Provide a schematic diagram of the emergency core cooling system (ECCS) and containment spray systems (CSS).*
2. *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.*
3. *Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions.*

4. *Provide a summary of the methodology, assumptions, and results of prototypical head loss testing for the strainer, including chemical effects. Provide bases for key assumptions.*
5. *Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen.*
6. *Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial thin bed formation.*
7. *Provide the basis for the strainer design maximum head loss.*
8. *Describe significant margins and conservatisms used in the head loss and vortexing calculations.*
9. *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation.*
10. *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis.*
11. *State whether the sump is partially submerged or vented (i.e., lacks a complete water seal over its entire surface) for any accident scenarios and describe what failure criteria in addition to loss of net positive suction head (NPSH) margin were applied to address potential inability to pass the required flow through the strainer.*
12. *State whether near-field settling was credited for the head-loss testing and, if so, provide a description of the scaling analysis used to justify near-field credit.*
13. *State whether temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. If scaling was used, provide the basis for concluding that boreholes or other differential-pressure induced effects did not affect the morphology of the test debris bed.*
14. *State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure.*

Response to Issue 3f1:

Diagrams of the Calvert Cliffs ECCS and CS system for Units 1 and 2 are provided in Attachment (2) to the submittal.

Response to Issue 3f2:

Calculations for minimum containment flood level have demonstrated that, for a small break LOCA (SBLOCA) and a large break LOCA (LBLOCA), the ECCS strainers will be completely submerged at the time of ECCS switchover to containment sump recirculation. The minimum calculated submergence level (level over the top of the strainer cassette) which occurs after the initiation of recirculation, is as follows:

- SBLOCA – 1" (Note: this is applicable to break sizes smaller than 0.08 ft^2)
- LBLOCA – 6"

Response to Issue 3f3:

Calvert Cliffs has completed vortex testing and analysis. CCI performed generic vortex testing for their strainer design in March 2005. The test results from those tests are used in the analysis which shows that vortexing is not possible at the design flows for the Calvert Cliffs strainers. Specifically, the Froude number for the Calvert Cliffs strainers is about 0.0025 (Fr = flow speed squared divided by the product of gravitational constant times the submergence depth) and the submergence of the strainer is about 25 mm minimum. Under such conditions, air ingestion via vortex development is not possible.

Additionally, vortexing was investigated at both minimum LOCA submergence depths, 1 inch for a SBLOCA and 6 inches for a LBLOCA. The flow rates investigated range from 80% of the design flow rate to more than 500% of the design flow rate. No vortexing was seen in any design basis head loss test. The large range in flow rates with no evidence of vortexing provides assurance that variations in flow across the strainer will not result in vortexing.

Vortex development may arise due to flow disturbances, possibly caused during pump start and stop cycles. The flow disturbances can produce boreholes in the debris bed which provide channels for high speed flow. Such high speed flow can induce vortexing. CCI testing for this phenomenon does produce local vortex formation. Based on CCI test results including tests specific for Calvert Cliffs, the critical Froude number for borehole induced vortexing is 62 and the plant Froude number is 55. (Here the Froude number is defined as follows: $Fr = 2 \times$ measured head loss $\div$ submergence depth.) The plant Froude number is lower than the critical Froude number for the submergence depth. Therefore, the strainer will not ingest air via vortices caused by boreholes.

Response to Issue 3f4:

Calvert Cliffs used the ECCS sump strainer supplier, CCI, to perform plant specific strainer head loss testing.

Two different test loop configurations were utilized for the Calvert Cliffs head loss testing, as follows:

1. Large Scale Test Loop Facility in Winterthur, Switzerland;
2. Multi Functional Test Loop (MFTL) at CCIs facility in Winterthur, Switzerland.

In each test one or more full-size strainer cartridges are placed in a test tank, and are subsequently loaded with the amount of debris computed to transport to this portion of the overall strainer. The volumetric flow rate is scaled so that the average velocity through the strainer cartridges corresponds to the expected average flow speed through the strainer installed in the plant during a LOCA.

Debris is introduced into the tank approximately 5 feet upstream of the test strainer. Fiber debris is shredded, and diluted in water to minimize agglomeration of fines. Chemical precipitates are generated in separate tanks according to the methods described in Reference 22.

Large Scale Test Loop Facility:

The Large Scale testing loop contained a two-sided strainer array with two CCI strainer cartridges per side, with 72 pockets per side placed in a pool that is filled with water (see Figure 3f4-1).

This testing provided further information into the expected head loss behavior of various types of debris.

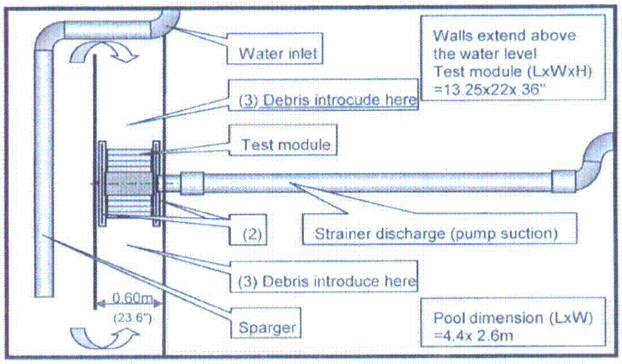

Figure 3f4-1
Outline of Large Scale Test Loop Facility

Multi Function Test Loop (MFTL):

The CCI MFTL is a closed recirculation loop as shown in Figure 3f4-2. The water recirculation in the loop occurs by means of a centrifugal pump with a flow rate capacity up to 125 m^3/h and a flow meter capacity of 80 m^3/h. The flow rate is adjustable by controlling the speed of the pump motor via a frequency based variable speed controller. Additionally the flow rate can be pre-adjusted by means of a valve in the downstream line. The water flow rate is measured using a KROHNE magnetic inductive flow meter. The temperature of the water is measured using a Ni-CrNi Thermocouple Type K.

The test program did not intend to take credit for near field debris settling. The debris was introduced about midway between the sparger and the test strainer module. The chemicals were introduced in the loop close to the sparger. The volume of water in the test loop is approximately 1700 liters.

Some debris settlement occurred in the MFTL testing. Most debris was transported into the strainer pockets by the flume flow but some settled to the floor of the flume. Agitation was used to suspend the settled debris. The agitation methods were successful at resuspending debris but were not successful at moving the settled debris into the pockets. In general, the pockets were full of fibrous and particulate debris prior to addition of chemical precipitate surrogates. The debris that did not enter the strainer pockets was found on the face of the strainer outside of the pockets or at the base of the strainer, within about 30 centimeters of the strainer. Far more debris is postulated to transport to the strainer than can fit into the strainer pockets. In essence, the strainer is full with debris and consequently is buried under the remaining debris load. (A photo of the test strainer with and without debris is provided in Figure 3f12-1.)

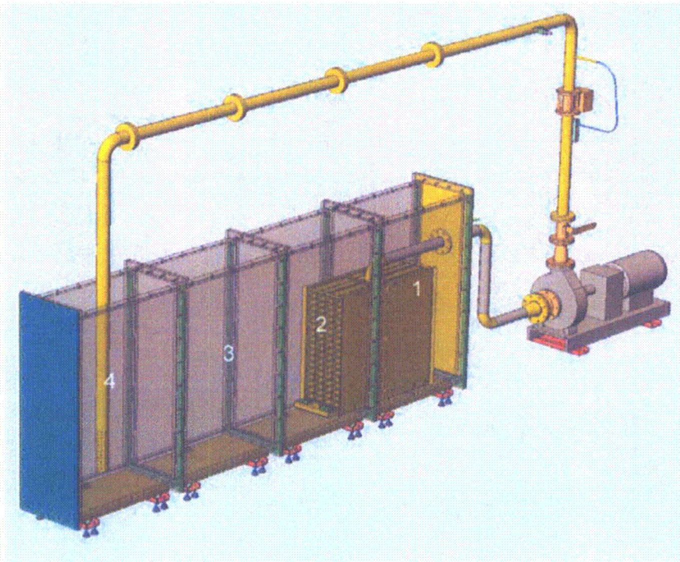

Figure 3f4-2
Outline of MFTL for Calvert Cliffs testing (4 modules shown)

The fibers used in the test were from materials identical to plant insulation, each with an as-fabricated density consistent with Reference 10, Section 3.5.2.3.

The debris preparation and addition methods used by CCI for the Calvert Cliffs tests are identical to those witnessed by the NRC in Spring 2008 at CCI's laboratory in Switzerland.

Fibrous debris for use in tests was prepared by the following method:

- Bake all fibrous insulation except generic fiberglass at 250°C for 24 hours. Generic fiberglass insulation is not baked for the tests since it is used at Calvert Cliffs on relatively cool pipes.
- Segment the insulation into small pieces approximately 50 mm cubed.
- Add about 25% of each type of fibrous insulation to a small amount of water to wet the insulation.
- Blast the slurry with a heated water jet at about 100 bar (1,500 psi) for at least four minutes.
- Visually inspect the resultant debris suspension to verify complete destruction to fines. Repeat water jet blast if not fully fines.
- Repeat until all fibrous insulation is prepared.

Fibrous concentration of the insulation debris suspension was about 0.4 pounds per cubic foot. Particulate debris was added to a suspension via mixing at a concentration of about 0.003 cubic feet of particulate per cubic foot of water. Neither type was mixed together; there were no mixed mode suspensions during preparation and addition. Both debris types were further diluted during the addition process but not uniformly. The normal test sequence was to alternate fibrous insulation additions and particulate additions during a single batch add. That is, one batch might consist of several containers of fibrous debris and several of particulate debris; additions of each type would be alternated until all of the batch was added.

Chemical precipitate was added about 3 meters upstream of the strainer.

Agglomeration was not observed. All debris was transported to the strainer module either directly or via resuspension in the flume flow through the action of agitation methods. Calvert Cliffs test methods are conservative in the delivery of material to the strainer.

The abbreviated procedure for performance of the tests is provided below.

1) Perform clean head loss test at 80% to 500% nominal flow rate.
2) Prepare fibrous insulation debris.
3) Prepare particulate by soaking in water.
4) Fiber / Particulate debris introduction:
   a) Ensure appropriate flow rate and water temperature per test plan.
   b) Add combined fiber and particulate debris about 1.5 meters in front of the strainer.
   c) Ensure transport to the strainer by appropriate agitation. Ensure appropriate distribution of debris across the strainer without center weighting.
   d) Add debris for thin bed investigation or for normal bed investigations as required in the test plan.
   e) Alternate fibrous and particulate additions per test plan.
   f) Maintain water level within tolerance.
5) Chemical precipitate introduction.
   a) Adjust flow rate per test plan.
   b) Add sodium aluminum silicate precipitate immediately adjacent to the sparger (return of flow from the heater to the test flume) per test plan. Use of a peristaltic pump is permitted and encouraged.
   c) Addition rate is specified in the plan but is intended to be slow enough to prevent spikes in the head loss measurements caused by overly rapid additions.
   d) Ensure transport of the debris bed by appropriate agitation.
6) Test termination Criteria are specified below:
   a) The test strainer head loss has stabilized and is not increasing and a minimum of 48 hours has elapsed since the final chemical addition was completed.
   b) After 96 hours has elapsed since the final chemical addition was completed with head loss still increasing.
   c) At the discretion of the Test Director for safety of personnel or equipment only.
7) Perform a flow sweep at the end of the test to demonstrate bed stability:
   a) Reduce flow rate to 80% nominal.
   b) Increase flow rate in increments to at least 120% of nominal. A few tests investigated flow rates as high as 250% of nominal.

The MFTL was heated to between 40-45°C for the Calvert Cliffs tests. The submergence was about 10 cm. The strainer test modules were elevated above the flume floor about 5 cm (about 2 inches) consistent with the plant installation. The strainer modules tested were identical to those installed in Calvert Cliffs.

The latest-quality assured testing was conducted in November and December, 2008. The maximum head loss observed was nearly 700 millibar and is used as the design head loss across the strainer for debris laden conditions; including chemical effects (see Response to Issue 3o2.26). Initial flow rates are nearly seven times the nominal and provide a clear basis supporting no vortex formation. (see Response to Issue 3f3) Flow sweeps were performed at the conclusion of the test to demonstrate stability of the bed.

Response to Issue 3f5:

The pockets in CCIs strainer cassettes are designed to fill with debris with additional debris depositing on the outside of the strainer. The spacing of the strainer module rows between each other and with plant structures allows sufficient space for the debris to accumulate without interfering with the debris from another strainer row. Therefore, there would be open space for flow around the accumulated debris for the postulated conservative debris volume.

Response to Issue 3f6:

The strainer installed at Calvert Cliffs is CCI's pocket cassette type strainer. Figure 3f6-1 shows a representative pocket cassette strainer. During the April/May 2008 testing and the October-December 2008 testing at CCIs MFTL, attempts were made to generate a thin bed using Calvert Cliffs-specific debris. The geometry of the pocket filtration surface is such that it was not possible to have a uniform fiber bed on the filtration surface.

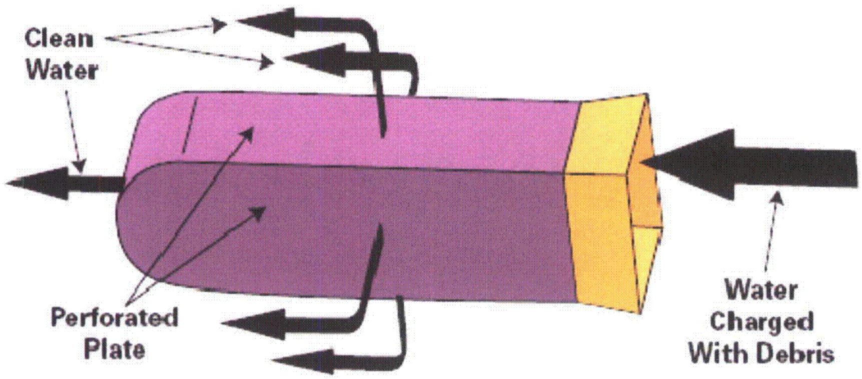

Figure 3f6-1
Pocket Cassette Strainer

The April-May 2008 tests used the following thin bed test methodology:

- Add 50% of the particulate and 10% of the fibrous debris (expected bed thickness 0.1 inch). Measure head loss.
- Add 50% of the particulate and 10% of the fibrous debris (expected total bed thickness 0.2 inches). Measure head loss.

The October-December 2008 tests used the following thin bed test methodology:

- Add 50% of the particulate and 10% of the fibrous debris (expected bed thickness 0.1 inch). Measure head loss.
- Add 50% of the particulate and 5% of the fibrous debris (expected total bed thickness 0.15 inches). Measure head loss.
- Add 5% of the fibrous debris (expected total bed thickness 0.2 inches). Measure head loss.

- Add 10% of the fibrous debris (expected total bed thickness 0.3 inches). Measure head loss.
- Add 10% of the fibrous debris (expected total bed thickness 0.4 inches). Measure head loss.
- Add 20% of the fibrous debris. Measure head loss.
- Repeat above step twice more. Final expected bed thickness 1.0 inch.

Calvert Cliffs thin bed testing included beds as thin as 1/16 inch up to a nominal full load of debris and included a wide range of simultaneous particulate loading. This ensures that the maximum head loss condition for the CCI strainers and for the Calvert Cliffs debris loads is identified. Maximum head loss occurs with maximum debris. No significant increase in head loss was seen in any thin-bed test. The CCI strainer exhibits no thin bed effect.

Response to Issue 3f7:

The acceptable maximum strainer head loss is based on ensuring adequate NPSH available to the pumps taking suction from the containment sump. The strainer head loss includes both the tested head loss across the strainer filtration surface, and the analytically computed head loss in the strainer duct channels.

The strainer postulated maximum head loss due to the maximum quantity of debris that was calculated to reach the screens, including chemical effects was determined by testing in October - December 2008.

The maximum head loss across the strainer perforated material and the accumulated debris including chemical precipitates is 710 millibar (10.2 psi), comprised of 700 millibar for the debris bed and strainer perforated face, and 10 millibar for the head losses internal to the strainer. The value of 710 millibar is highly dependent on the postulated conditions for the test which were that all dissolved aluminum precipitates and the resultant particles are captured by the accumulated debris bed.

Response to Issue 3f8:

One key conservatism for the hydraulic analyses is the assumption that all small fines transport to the sump strainer. Testing at CCI's MFTL has shown quantities of settled small fines even in an agitated test pool. Substantially all debris was found in the pockets of the test strainer, on the face of the test strainer, or at the base of the test strainer. The approach velocities into the Calvert Cliffs strainer account for the observed debris transport behavior. We understand that other CCI customers did not observe this phenomenon because their flow rates were higher. The fact that the strainer flow rate is so small that fines tend to settle, even at the inlet to the strainer, indicates a conservative overall design.

Response to Issue 3f9:

The clean strainer head loss across the filtration surface as measured in CCI's Large Scale Test Loop Facility was approximately zero. This head loss was confirmed in the demonstration testing performed in the MFTL.

The head loss in the axial flow channel between cartridges and in the radial duct is computed using formulas in Reference 15. Based on the computed Reynolds Number (1.64×10^6), flow formulas applicable to turbulent flow are used.

Influx flow from the side (i.e., through the cartridges) into the axial flow channel is considered. The friction drag coefficient is developed from the well-known Moody friction curves. A friction factor of 0.025 is used which is conservative for high Reynolds numbers. A relative roughness of 0.001 is used for the smooth stainless steel.

Head loss due to flow obstructions (i.e., seven stabilizer plates within the strainer assembly) and enlargements in the flow stream are considered using equations from Reference 15. The computed analytical head loss for the strainer interior for the design flow rate is approximately 4.2" WC (10 millibar).

Response to Issue 3f10:

A debris head loss analysis was performed by CCI during the sizing of the strainer using the equations from Reference 16. This analysis has been superseded by scaled head loss testing.

Therefore, the governing head loss analysis consists of the analytically determined head loss of the strainer internals (see Response to Issue 3f9), and test results of the head loss across the debris bed on the filtration surface (see Response to Issue 3f4).

Response to Issue 3f11:

The ECCS sump screens are fully submerged under all accident scenarios that include ECCS recirculation. There is no vent above the water level.

Response to Issue 3f12:

The head loss testing with chemical effects conducted in 2008 did not involve debris settling. Settling distant from the test strainer was prevented by careful debris addition and agitation in the test loop. All debris added to the test reached the strainer. However, not all debris entered the strainer pockets. With the large quantity of fibrous debris and the careful debris preparation which produced fines, individual fibers, and minimal clumps the resultant debris volume exceeded the volume of the strainer pockets. Hence, most of the fibrous debris attached to the front of the strainer. Some debris attached to the edges of the strainer, some 'settled' on top of the test strainer module, and some attached or 'settled' to the lower face of the strainer. See Figure 3f12-1 below. A relatively uniform debris mass protrudes approximately six inches from the entrance to the strainer pockets. The lower portion of that mass forms a ramp of debris supported by the test flume floor immediately at the base of the test strainer and is about 12 inches high and about 12 inches long. The portion that is partially supported by the flume floor is generally about 20% of the total. The balance is in the pockets or attached to the face of the strainer (about 72%), or has settled on top of the strainer test module (about 8% of the total).

Figure 3f12-1
Unloaded and Debris Laden Test Strainer - CCI MFTL

Agitation was used to ensure transport of all forms of debris to the entrance of the strainer. Debris transport that would bound what might transport during an accident was achieved in the head loss testing. Great care was used to prevent debris bed disturbances. Photographic and video records show that the test debris beds remain undisturbed during agitation.

Also, note that Calvert Cliffs does not use a computational fluid dynamics analysis to compute the amount of debris that transports to the strainer, but instead assumes the transport fractions provided in Reference 10.

Response to Issue 3f13:

No scaling via temperature dependent dynamic viscosity was used.

Response to Issue 3f14:

Containment accident pressure is not credited in evaluating whether flashing occurs across the strainer surface.

Calvert Cliffs test results show that the clean strainer head loss is about 0.1 to 0.2 millibar at more than 5 times the nominal flow rate. With the full debris load (mechanical debris only without chemical precipitates) added to the strainer, the strainer head loss test result is about 5 millibar (about 2 inches WC) at nominal flow rate and 12 millibar (5 inches WC) at 270% of nominal. The large-break LOCA submergence, which is 6 inches submergence, is greater than these values. Therefore, no flashing would occur in a large-break LOCA condition at the start of recirculation.

Small-break LOCAs are not expected to generate sufficient debris to uniformly cover the entire strainer. Therefore, their lesser submergence, which is greater than the clean strainer head loss, will not cause flashing to occur at the start of recirculation. Once chemical effects are included, the head loss is potentially much greater. Chemical precipitates are predicted to impact head loss only once the sump pool has cooled to a temperature below 140°F. The NPSH margin available at these temperatures due to sub-cooled conditions is sufficient to avoid vapor formation even at the high head losses associated with chemical effects.

NRC Issue 3g:

Net Positive Suction Head (NPSH)

The objective of the NPSH section is to calculate the NPSH margin for the ECCS and CSS pumps that would exist during a loss-of-coolant accident (LOCA) considering a spectrum of break sizes.

1. *Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level.*
2. *Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions.*
3. *Provide the basis for the required NPSH values, e.g., three percent head drop or other criterion.*
4. *Describe how friction and other flow losses are accounted for.*
5. *Describe the system response scenarios for LBLOCA and SBLOCAs.*
6. *Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation.*
7. *Describe the single failure assumptions relevant to pump operation and sump performance.*
8. *Describe how the containment sump water level is determined.*
9. *Provide assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin.*
10. *Describe whether and how the following volumes have been accounted for in pool level calculations: empty spray pipe, water droplets, condensation and holdup on horizontal and vertical surfaces. If any are not accounted for, explain why.*
11. *Provide assumptions (and their bases) as to what equipment will displace water resulting in higher pool level.*
12. *Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source.*
13. *If credit is taken for containment accident pressure in determining available NPSH, provide description of the calculation of containment accident pressure used in determining the available NPSH.*
14. *Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature.*
15. *Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.*
16. *Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.*

Response to Issue 3g1:

The containment sump feeds both trains of the ECCS and CS system. When the ECCS switchover from the refueling water tank (RWT) to the sump is completed, each train, consisting of a HPSI pump and a CS pump, takes suction from the sump. The maximum flow rate from the sump occurs when both trains of HPSI and CS pumps take suction from the sump.

Maximum HPSI pump flow rate = 1060 gpm (two pumps operating)
Maximum HPSI pump flow rate = 650 gpm (one pump operating)
Maximum CS pump flow rate = 1730 gpm per pump, maximum two pumps operating

Strainer design flow = 5000 gpm

The condition of a LPSI pump failure to stop at recirculation actuation signal (RAS) may increase the flow rate. This has been considered in testing and evaluations.

Maximum post-RAS sump temperature
= 196.4°F for cold leg break LBLOCA with two safety trains operating
= 218.4°F for cold leg break LBLOCA with one safety train operating
= 219.4°F for hot leg break LBLOCA with one safety train operating

Minimum Containment water level = 3'-6.9" (LBLOCA)
Minimum Containment water level = 3'-1.9" (LOCAs smaller than 0.08 ft^2)

Note that the maximum post-RAS sump water temperature noted above for the condition of one safety train operating would require containment pressure to be elevated above normal atmospheric pressure for Calvert Cliffs. Where sump water temperature exceeded 212°F, the vapor pressure of the sump fluid is set equal to the containment pressure (i.e., 14.7 psia). This approach is similar to that found in Reference 32, Section 1.3.

Response to Issue 3g2:

The assumptions used for the above analysis are:

- HPSI flow rate is throttled as directed by procedure but with the upper bound uncertainty of flow indication applied to the assumed flow rate in all calculations of NPSH.
- CS flow rate is that predicted by a hydraulic flow model where the containment spray flow rate is upgraded 10% above the vendor pump curve which bounds the tested performance of the pumps.
- The diesel generator is assumed to be at 2% over-frequency which bounds the performance of the emergency diesel generator.

Response to Issue 3g3:

The NPSH required values are provided on the vendor pump curve as a function of flow rate.

The original test data for the CS pumps was used to determine the NPSH. The CS pump was tested at decreasing NPSH available values at a given flow rate. The last data point taken during testing was that NPSH available value where a decrease in total developed head was observed. The NPSH required value was then established as the second to last tested NPSH available value (i.e., the lowest one for which no decrease in total developed head was detected).

Similar data for Calvert Cliffs HPSI pumps could not be recovered from plant history records. However, correspondence with the HPSI pump vendor (Sulzer) regarding testing they did for another client having an identical pump indicates that the NPSH required values on the pump curve are based on a 3%

degradation in the pump total developed head. The 3% degradation point is a pump industry standard for reporting NPSH required.

Response to Issue 3g4:

Hydraulic friction losses in the strainer flow channels are accounted for as described in the Response to Issue 3f9. Hydraulic friction flow losses in the ECCS recirculation suction supply piping are computed using a hydraulic model of the ECCS piping. The NPSH available to the HPSI and containment spray pumps is obtained by subtracting these hydraulic friction losses from the static head differential between the containment water height and the pump suction elevation.

Response to Issue 3g5:

The ECCS consists of three HPSI pumps, two LPSI pumps, and four safety injection tanks (SITs). Each HPSI pump injects into one of two high pressure injection headers, both of which feed each cold leg. The LPSI pumps inject into a low pressure injection header that feeds each cold leg. Each SIT injects into a single cold leg. Two HPSI pumps and the LPSI pumps are automatically actuated by a safety injection actuation signal that is generated by either a low pressurizer pressure (<1725 psia) or a high containment pressure signal (>4.75 psig). The SITs automatically discharge when the RCS pressure decreases below the SIT pressure.

LBLOCA

The HPSI and LPSI pumps automatically start when the pressurizer pressure is less than or equal to 1725 psia, or containment pressure is greater than or equal to 4.75 psig. Actual HPSI pump flow to the core will not begin until the pressurizer pressure is approximately 1280 psia, and actual LPSI pump flow to the core will not begin until the pressurizer pressure is approximately 185 psia.

The CS pumps automatically start on safety injection actuation signal setpoint, low pressurizer pressure. Afterward, flow to the containment environment is delayed only by the time required to fill the empty CS headers as soon as the spray control valve begins to open at a containment pressure of 4.75 psig. Containment air coolers will also start at a containment pressure of 4.75 psig with their associated delay for heat removal from Containment.

The SITs automatically discharge to the RCS when the RCS pressure drops to about 200 – 250 psig.

Initially, all safety injection pumps take suction from the RWT. When the RWT reaches its low-low level signal, a RAS is generated, and HPSI and CS pumps suction switches from the RWT to the containment sump. The LPSI pumps are automatically stopped when the RAS is generated.

The HPSI flow is throttled post-RAS to a constant valve. Throttling of the HPSI flow rate may be implemented to match the decreasing rate of heat addition to the RCS by the decay heat. Containment spray flow continues until the containment atmosphere temperature decreases to 120°F or less at which point one spray pump is turned off.

SBLOCA

The same automatic actuations exist for a SBLOCA. However, for a SBLOCA where the pressurizer pressure remains high for an extended period of time, the Operators may take actions to secure the LPSI pumps to avoid running on mini-flow recirculation for an extended period of time. Also, for SBLOCAs the SITs may be isolated prior to these tanks injecting into the RCS.

Response to Issue 3g6:

The following table describes the operational status of the ECCS and CS pumps before and after the start of recirculation.

Pump	Injection Phase	Recirculation Phase
HPSI (maximum 2 of 3)	On	Throttled
LPSI	On	Off
CS	On	On

Response to Issue 3g7:

Three design basis cases are used to establish the design limits for pump operation and sump performance. Both a hot leg break and a cold leg break are analyzed assuming the failure of a diesel generator (and therefore, the failure of a safety train) as the limiting single failure. A cold leg break is also analyzed assuming the failure of a train of the Service Water System, resulting in reduced cooling. The results of these cases are given in the Response to Issue 3g1.

One additional single failure case was evaluated (failure of one LPSI pump to turn off upon initiation of recirculation). This single failure would cause additional flow through the strainer, the accumulating debris bed, and the suction piping from the strainer to the pumps. This was analyzed in the NPSH margin calculations and found acceptable.

Response to Issue 3g8:

The containment sump water level assumes minimum inventory from the RWT is delivered to the RCS. Water used to fill the containment spray and other piping is considered. The RCS volume is not assumed to empty into the sump pool. Hold up of water in the refueling pool cavities is assumed to occur as is hold up of water in the reactor cavity. Safety injection tank inventory is considered for LOCAs greater than 0.08 ft^2. No chemical control fluid storage volumes are credited because the charging pumps are not safety-related.

Response to Issue 3g9:

The conservatism of the minimum containment water level is maintained by minimizing the sources of water and by maximizing the volume of water entrapment. Some of the specific examples of water sources that are minimized are given below:

- Minimum RWT inventory
  - minimum initial RWT volume allowed by Technical Specifications
  - RAS occurs at earliest point in setpoint band
  - no water transfer from RWT post-RAS even though it is the preferred source for an additional minute due to valve operation times
- RCS inventory assumed to remain in RCS (very conservative for a LBLOCA).
- The sump piping assumed empty up to sump valves.
- The current sump level calculation assumes the reactor cavity holds up water even though a 4" drain that drains through a 2" valve and pipe exists in this compartment.

Response to Issue 3g10:

The containment spray pipe and other selected pipes are assumed to be empty for the water level calculation.

The hold up of water on horizontal surfaces was investigated and it was found that a 1/16" film would account for approximately 450 gallons. This was considered to be bounded by the assumption that no RCS volume contributes to the sump pool volume.

The outer wall of Containment is not close enough to the spray nozzles for the containment spray to effectively reach them. The surface areas of the other vertical surfaces that could be sprayed are not sufficient to affect the water level calculation.

Condensation of water vapor released from the RCS and subsequently condensed onto surfaces is bounded by the assumption that the RCS and pressurizer volumes do not contribute to the containment pool volume.

Spray droplets in motion from the spray nozzles to any intersecting surface were not specifically considered in the minimum pool depth analysis.

Response to Issue 3g11:

In the sump water level calculation, the volume occupied by concrete pillars is considered in the displacement of water. No other equipment or structures in the sump pool are assumed to displace the water.

Response to Issue 3g12:

The following water sources are considered as contributors to the containment post-accident pool volume:

- RCS - The RCS inventory assumed to remain in RCS and does not contribute to the containment post-accident pool volume.
- RWT – It is assumed that the RWT provides 49,640 ft^3 of water that empties to the lower level of Containment. This assumes the RWT is at the minimum water level allowed by the low-level alarm setpoint (including uncertainty) at the start of the accident. It also assumes that RAS occurs at the highest value in the setpoint band, and furthermore that no water transfers from the RWT after a RAS is reached even though the RWT will be discharging inventory to the RCS for over a minute after that time.
- Safety Injection Tanks – For LOCAs greater than 0.08 ft^2 in size it is assumed that the inventory from four SITs inject into the RCS. The minimum volume of 1113 ft^3 per SIT (Technical Specification 3.5.1) is assumed to inject into the core. Since only passive components separate the SITs from the RCS at the start of an accident the inventory from all four SITs is assumed to empty to the RCS.

Response to Issue 3g13:

Credit is not taken for containment accident pressure in determining the available NPSH. See Response to Issue 3g1.

Response to Issue 3g14:

Containment pressurization is not considered in our pump NPSH calculations. The containment initial pressure is assumed to be the minimum allowed by Technical Specifications. All LOCA cases have sump water temperature above 212°F at some point and two of them have sump water temperature above 212°F at the start of recirculation. See Response to Issue 3g1. The containment accident pressure assumptions are given in Response to Issue 3g1.

The sump pool temperature calculation assumes a single failure of one emergency diesel generator resulting in a loss of one ECCS train (including HPSI and CS pumps and containment air cooler), or the loss of one containment air cooler train and loss of one decay heat removal heat exchanger. There is no sump cooling since heat transfer to the containment basemat is not credited in the analysis. The sump pool temperature analysis also neglects any cooling from the sump pool by means of evaporation. Finally, a containment pressure of 14.7 psia (as compared to 16.5 psia) is assumed along with 100% humidity. All of these factors result in a conservatively high prediction of sump pool temperature.

Response to Issue 3g15:

For the NPSH calculation atmospheric pressure is used as the containment pressure during a LOCA. Note that all design basis LOCA scenarios for Calvert Cliffs result in sump fluid temperatures exceeding 212°F. For NPSH calculations where the sump fluid temperature exceeds 212°F, the vapor pressure of the sump fluid is assumed equal to the containment pressure.

Response to Issue 3g16:

Below is the minimum NPSH margin (NPSH Available minus NPSH Required) at various containment sump pool temperatures:

Pump	**$NPSH_A$**	**$NPSH_R$**	**Margin**
140°F			
HPSI	23.9 ft	15.0 ft	8.9 ft
LPSI	28.8 ft	22.7 ft	6.1 ft
130°F			
HPSI	25.4 ft	15.0 ft	10.4 ft
LPSI	30.4 ft	22.7 ft	7.7 ft
120°F			
HPSI	26.7 ft	15.0 ft	11.7 ft
LPSI	32.6 ft	22.7 ft	8.9 ft
110°F			
HPSI	27.6 ft	15.0 ft	12.6 ft
CS	32.6 ft	22.7 ft	9.9 ft

The margins above include the head loss across the strainer and strainer filter including debris bed at all temperatures and chemical effects at the temperatures listed above.

These margins also include the pressure difference between the assumed containment pressure and the vapor pressure of the sump water (sub-cooled margin) for sump water temperature below 212°F.

NRC Issue 3h:

Coatings Evaluation

The objective of the coatings evaluation section is to determine the plant-specific zone of influence and debris characteristics for coatings for use in determining the eventual contribution of coatings to overall head loss at the sump screen.

1. *Provide a summary of type(s) of coating systems used in Containment, e.g., Carboline CZ 11 Inorganic Zinc primer, Ameron 90 epoxy finish coat.*
2. *Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.*
3. *Discuss suction strainer head loss testing performed as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris.*
4. *Provide bases for the choice of surrogates.*
5. *Describe and provide bases for coatings debris generation assumptions. For example, describe how the quantity of paint debris was determined based on zone of influence size for qualified and unqualified coatings.*
6. *Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.*
7. *Describe any ongoing containment coating condition assessment program.*

Response to Issue 3h1:

A Bechtel construction specification was used to specify the coatings used during plant construction. It identifies the original primers used in Containment as Dimetcote No. 6 (also known as D6) and Mobilzinc 7. The original topcoats were Amercoat 66 and Mobil 89 Series.

Coatings that have been used at Calvert Cliffs since construction are identified in internal plant documents. These documents identify the primer, topcoat, and application standard to be used on the various surfaces inside Containment. A primer of Ameron D6 and a topcoat of Ameron 66 are the primary coatings referenced; however, Valspar 13F12 is used as a primer on some surfaces and Valspar 89 is used as the corresponding topcoat. Valspar 13F12 is the same as Mobilzinc 7 and Valspar 89 is the same as Mobil 89 Series.

New coatings are listed as Ameron 90, and Carboline 890. An additional update lists the metal primer as Carboline Carboguard 890, the concrete primer as Carboline Starglaze 2011S, and the topcoat as Carboline Carboguard 890.

Response to Issue 3h2:

All coatings in the zone of influence and all coatings of unknown pedigree (i.e., no proof it was ever qualified) are assumed to fail as 10 μm particles and transport to the sump.

As discussed in Response to Issue 3c4 and Issue 3e1, for coatings that were installed as qualified, but subsequently found to be degraded per site inspection procedures, a portion of the coatings are assumed to fail as chips. Credit was then taken, as applicable, for the Reference 14 study that demonstrated paint chips will not transport in sump pool velocities less than 0.2 ft/sec.

Degraded qualified coatings systems used at Calvert Cliffs are of a comparable nuclear grade to those tested by Keeler and Long. Calvert Cliffs verified that the coatings applied were of a nuclear grade comparable to those in the K&L report (Reference 11). However, the inorganic zinc primers will fail as particulates and the epoxy top coats will fail as chips (greater than 1/32").

Additional testing was performed to investigate the transportability of coatings chips. The test of transportability of coatings chips used coating chips size distribution of 1-4 mm. Results of transport test for these coating chips are provided in Figure 3h2-1 below. These results show that at high flow rates, 8 times nominal, average transport is well under 1 meter (40 inches) from the introduction point for settlement equal to the entire depth of the containment pool. The test flow rates were much greater than expected in the plant post-LOCA. Transport distances are negligible for the size of the Containment at Calvert Cliffs.

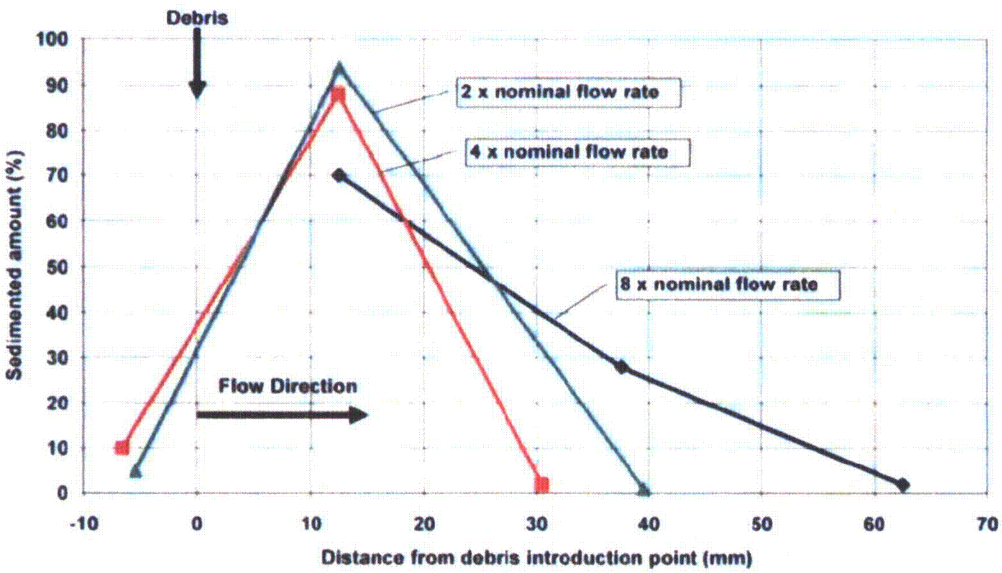

Figure 3h2-1
Coating Transport Test Results

Response to Issue 3h3:

The head loss testing used scaled quantities of coatings as part of the strainer debris load. Stone flour was used as a surrogate material for unqualified coatings that were assumed to fail as 10 μm particles. Epoxy particulate with a median particle size of 10 microns was used to simulate qualified coatings that are destroyed within the zone of influence. During the initial and scoping testing actual paint chips made of Carboline Carboguard 890 were placed in the test tank to assess the effect of these chips on the debris bed. Since these chips fell directly to the bottom of the tank even when introduced right at the face of the strainer, it was concluded that the Reference 14 coatings transport test data which showed the non-transportability of paint chips at velocities less than 0.2 ft/sec were applicable to our strainer installation. No further introduction of paint chips into the test was considered.

Any paint chips introduced to the debris bed during testing disrupted the debris bed and lowered the head loss.

Response to Issue 3h4:

Stone flour was used because its size (average surface area corresponding to 10 μm diameter) and its high degree of transportability matched that of the coatings it represents. Epoxy particulate was used to simulate epoxy coatings generated from within the zone of influence because epoxy within the zone of influence is postulated to become particulate with no chips or flakes. Design basis tests also used

Sil-Co-Sil 40 to simulate coatings particulate because of its transportability and because its size distribution closely matches that of the failed coatings particulate debris.

Response to Issue 3h5:

Calvert Cliffs has followed the guidance from Reference 10 for determining the quantity of coating debris. Per Reference 10, Section 3.4.2.1:

- All coating (qualified and unqualified) in the zone of influence will fail,
- All qualified (design basis accident-qualified or acceptable) coating outside the zone of influence will remain intact,
- All unqualified coatings outside the zone of influence will fail.

From Reference 7, a zone of influence of 4.0 L/D was used for epoxy-based coatings, and a zone of influence of 5.0 L/D was used for un-topcoated inorganic zinc primer. All unqualified coatings (including degraded qualified coatings) were assumed to fail, as noted above.

Response to Issue 3h6:

See the Response to Issue 3h2 above.

Response to Issue 3h7:

Calvert Cliffs conducts condition assessments of Service Level I coatings inside the Containment once each refueling cycle at a minimum. Generally, all of the accessible areas within the Containment are visually inspected. As localized areas of degraded coatings are identified, those areas are evaluated and scheduled for repair or replacement, as necessary. The periodic condition assessments, and the resulting repair/replacement activities, assure that the amount of Service Level I coatings that may be susceptible to detachment from the substrate during a LOCA event is minimized and is identified and tracked by the plant coatings condition assessment program.

***NRC Issue 3i*:**

Debris Source Term

The objective of the debris source term section is to identify any significant design and operational measures taken to control or reduce the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions.

1. *Provide the information requested in GL 04-02 Requested Information Item 2(f) regarding programmatic controls taken to limit debris sources in Containment.*

GL 2004-02 Requested Information Item 2(f)

A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced into Containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. Addressees may reference their responses to GL 98-04, "A Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of- Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment," to the extent that their responses address these specific foreign material control issues. In responding to GL 2004 Requested Information Item 2(f), provide the following:

2. *A summary of the containment housekeeping programmatic controls in place to control or reduce the latent debris burden. Specifically for RMI/low-fiber plants, provide a description of programmatic controls to maintain the latent debris fiber source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid.*
3. *A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the Containment.*
4. *A description of how permanent plant changes inside Containment are programmatically controlled so as to not change the analytical assumptions and numerical inputs of the licensee analyses supporting the conclusion that the reactor plant remains in compliance with 10 CFR 50.46 and related regulatory requirements.*
5. *A description of how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65.*

If any of the following suggested design and operational refinements given in the guidance report (guidance report, Section 5) and SE (SE, Section 5.1) were used, summarize the application of the refinements.

6. *Recent or planned insulation change-outs in the Containment which will reduce the debris burden at the sump strainers*
7. *Any actions taken to modify existing insulation (e.g., jacketing or banding) to reduce the debris burden at the sump strainers*
8. *Modifications to equipment or systems conducted to reduce the debris burden at the sump strainers*
9. *Actions taken to modify or improve the containment coatings program*

<u>*Response to Issues 3i1 and 3i2*</u>:

Several Calvert Cliffs' procedures and practices are in place to ensure containment cleanliness is maintained and that debris inside Containment is identified and minimized prior to power operations. Site procedures require that specific inspections be performed and documented for loose debris prior to containment closeout and an "intense" search be made of Containment prior to entering Mode 4 for sources of loose debris and corrective actions taken. Another procedure assigns specific ownership responsibilities for plant areas including Containment when accessible, and requires weekly cleanliness inspections and prompt actions to remediate. Calvert Cliffs has also developed a good practice of performing daily containment walk downs during refueling outages specifically for cleanliness issues and generating daily containment cleanliness key performance indicators which are tracked, reported on, and managed.

<u>*Response to Issue 3i3*</u>:

A Constellation Energy fleet procedure contains guidance specifically addressing foreign material exclusion (FME) concerns in areas like the Containment and the containment sumps. It classifies the containment sumps as a Special Foreign Materials Exclusion Area, and requires an FME project plan for any entry into the sumps. Foreign material exclusion project plans are prepared, reviewed, and approved. The requirements of this procedure are stringent with regard to standards but allow flexibility for adapting an FME project plan for any kind of maintenance evolution. This procedure also requires FME training for all personnel working in Containment.

<u>*Response to Issue 3i4*</u>:

A Calvert Cliffs site procedure contains specific guidance in the impact screening process for analyzing the impact of changes that could affect thermal insulation and containment response to accidents.

Another site procedure controls the requirements for research on the part of maintenance planners for maintenance which could introduce new debris sources into Containment. The procedure is being revised to require that for any maintenance activity that will install any materials in either Unit 1 or Unit 2 Containments expected to remain there during Mode 4 or higher operations, engineering reviews the installation details for impact on the containment sump strainer analyses and must approve the usage of these new materials.

Response to Issue 3i5:

A Calvert Cliffs site procedure establishes requirements for effective implementation of the Maintenance Rule program at the site. It describes approved methods to monitor, trend, establish and modify goals for system, structures and components. Additional site procedures for integrated work management and integrated risk management provide specific guidance on risk assessment and scheduling of maintenance and temporary changes.

Response to Issues 3i6 and 3i7:

For Units 1 and 2, calcium-silicate pipe insulation within 17 L/D of the RCS piping was banded on 2 3/4" centers to reduce the zone of influence to 3 L/D. Calcium-silicate pipe insulation outside of 17 L/D was banded at 6" centers. Any calcium-silicate insulation within 3 L/D of the RCS piping was replaced on Units 1 and 2 with fiberglass insulation.

For margin improvement, the two pipes in Unit 1 will have insulation removed during the 2010 RFO. The pipes are the shutdown cooling line insulated with mineral wool insulation and the pressurizer relief valve line outside of the pressurizer compartment insulated with generic fiberglass insulation. The corresponding pipes in Unit 2 are uninsulated.

Response to Issue 3i8:

Valve equipment tags are now made of materials that would sink in water and not transport to the containment sump. In addition, the tags will not delaminate in a post-accident environment. Calvert Cliffs investigated re-coating the reactor coolant pump motors with qualified coatings to reduce the unqualified coating debris load (approximate surface area is 2000 ft^2 per Unit). The reactor coolant pump motor coating was verified to be qualified and no further action is required.

Response to Issue 3i9:

Calvert Cliffs has an existing coatings program that monitors and controls the quantities and types of coatings installed inside Containment. As noted in Reference 17, Calvert Cliffs has implemented controls for procurement, application, and maintenance of qualified coatings used inside Containment that are consistent with the licensing basis and regulatory requirements. This program conducts periodic condition assessments, typically each outage, to verify the adequacy of existing coatings and direct repair/replacement, as necessary. The quantity of unqualified coatings that are added inside Containment is tracked. This program is adequate in its current form to ensure coatings are properly controlled, and that future installations of unqualified coatings are quantified.

NRC Issue 3j:

Screen Modification Package

The objective of the screen modification package section is to provide a basic description of the sump screen modification.

1. *Provide a description of the major features of the sump screen design modification.*

2. *Provide a list of any modifications, such as reroute of piping and other components, relocation of supports, addition of whip restraints and missile shields, etc., necessitated by the sump strainer modifications.*

Response to Issue 3j1:

In Calvert Cliffs Units 1 and 2, a strainer of 6000 ft^2 filtration surface area (nominal) has been installed. The strainer is CCI's cassette pocket strainer design. The hole size through the filtration surface is 1.6 mm (1/16") with no more than 3% larger holes and no holes larger than 2 mm (0.08"). There are 33 strainer modules divided among three strainer rows. These modules are approximately 3' high. There are 324 pockets in 29 of the strainer modules, and 252 pockets in four of the strainer modules. The pocket dimensions are 75 mm x 75 mm in cross-section, and 200 mm deep. The strainer rows tie into a common duct which directs the flow to the existing containment sump. The containment sump is a concrete curb with a steel roof, and contains the inlets to both recirculation headers. See Figure 3j1-1.

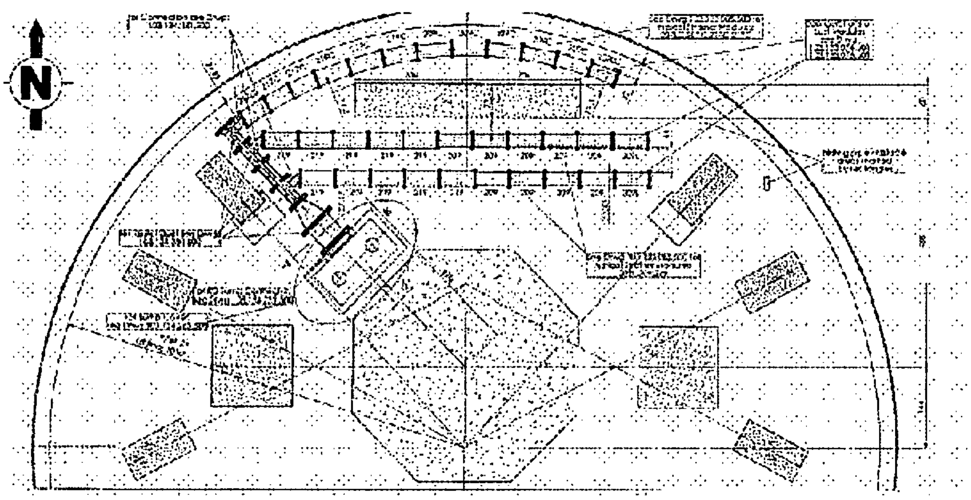

Figure 3j1-1
Strainer Arrangement

Response to Issue 3j2:

A 16" feedwater pipe support was modified on Unit 2 to allow clearance for one of the strainer rows. A cable tray support was also modified on Unit 2 to allow clearance for the radial duct. These modifications were not required on Unit 1. In addition, the 6" curb around the ECCS sump was notched to allow for installation of the common duct to the sump.

NRC Issue 3k:

Sump Structural Analysis

The objective of the sump structural analysis section is to verify the structural adequacy of the sump strainer including seismic loads and loads due to differential pressure, missiles, and jet forces. Provide the information requested in GL 2004-02, "Requested Information," Item 2(d)(vii), that is, provide verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions.

1. *Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.*
2. *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.*
3. *Summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy line breaks (as applicable).*
4. *If a backflushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow.*

Response to Issue 3k1:

Classical and finite-element (ANSYS or ME035) methods were used to analyze the following parts of the strainer:

- Standard cartridges (cartridge depth 200 mm)
- Support structure and duct of a standard module
- Radial duct
- Sump cover

Note that the Response to Issue 3k2 below provides descriptions of these strainer parts.

The strainers and their supports were analyzed according to the rules of Reference 18 for Class 2 components. These rules were chosen to provide a recognized standard for structural analyses, however, the strainer components are non-American Society of Mechanical Engineers code items, Seismic Category 1.

The standard module analysis assumes an 18 cartridge design which envelopes the smaller 14 cartridge design.

The design codes used for the sump structural strainer analysis are References 19 and 20.

Design Inputs

Total weight of modules (2 support structures, duct, cover plate, and cartridges)
18 Cartridge Module 906.9 lbm (411.37 kg)
14 Cartridge Module 767.9 lbm (348.30 kg)

Total debris mass transported to sump = 10,782.81 lbm (4891 kg)
(Note: this is an enveloping value used for structural analyses only)

With the sodium tetraborate decahydrate (STB) buffer, the differential pressure determined by WCAP-16530-NP based tests is 10.15 psi (700 millibar) at 70°F (21°C). No aluminum based precipitate effects occur for greater temperatures. However, based on ANL test results as described in Enclosure 1, Calvert Cliffs conservatively assumes that aluminum will precipitate out as sodium aluminum silicate and affect head loss at a temperature below 140°F.

For both Units:
Operating Basis Earthquake
Maximum Horizontal Acceleration ≈ 1.96 g at ≈ 4 Hz
Maximum Vertical Acceleration ≈ 0.59 g at ≈ 10 Hz

Safe-Shutdown Earthquake
Maximum Horizontal Acceleration ≈ 2.75 g at ≈ 5 Hz
Maximum Vertical Acceleration ≈ 1.11 g at ≈ 10 Hz

Additional load from shielding blankets = 885.91 lbf (3940.76 N)

Summary of Design Load Combinations

The load combinations are summarized in Table 3k1-1 below.

Table 3k1-1
Load Combinations Used in ECCS Sump Screen Verification

#	Load Combination Type	Temperature (°F)	Temperature (°C)
1	W(pool dry)	280	137.8
2	W+OBE(pool dry)	280	137.8
3	W+SSE(pool dry)	280	137.8
4	W+OBE(pool filled)	280	137.8
5	W+SSE(pool filled)	280	137.8
6	W+WD+OBE(pool filled)+ΔPD	70(220)	21(104.4)
7	W+WD+SSE(pool filled)+ΔPD	70(220)	21(104.4)
8	W+AddL	70	21

Variables:

W	weight of strainers & supporting structures
WD	weight of debris
ΔPD	pressure differential
OBE	operating basis earthquake
SSE	safe-shutdown earthquake
AddL	additional load caused by radiation shielding blankets

For the OBE and SSE cases, a sloshing load also was computed to account for the impact of water sloshing in the sump pool.

Response to Issue 3k2:

The ECCS sump strainer structure consists of two separate structures: the floor structures, and the sump pit structures.

The floor structures consist of the strainer modules themselves which provide the filtration surface area, and a radial duct which channels the flow from the three rows of strainer modules to the sump pit. The radial duct consists of six segments each approximately 4' long. There are 29 strainer modules that are approximately 5' long, and four strainer modules that are approximately 4' long. Each of these strainer modules/radial duct segments are anchored to the concrete floor via an anchor plate at each end. There are four anchor bolts (½" Hilti bolts at 3½" minimum embedment torqued to 40 ft-lbs) on each anchor plate. A retaining structure is mounted on top of each anchor plate. This retaining structure provides the mounting frame for the radial duct segments and the interior duct of the strainer modules. The various connections are made using M12, M16, and M20 bolting hardware. The retaining structures are attached to the anchor plates using two M30 bolts. The strainer cassettes (filter surface) attach to the strainer interior duct, and are covered with a deck plate.

The sump pit structure consists of cover plates which covers the sump pit and support beams fixed on and about a concrete curb and additionally supported by short columns that bear directly on the sump floor. Two pairs of mounting brackets are anchored to the concrete curb using four anchor bolts (½" Hilti bolts at 3½" minimum embedment torqued to 40 ft-lbs) on each bracket.

Brackets are used to locate the two side beams. A pair of posts support each side beam and are anchored in a similar fashion as above. Three posts, one at each end and one in the center support the middle beam.

The beams noted above are 140 mm x 140 mm I-beam and are fastened to these mounting brackets/mounting posts.

Ratios of design stress and corresponding allowable stress for various components of the ECCS sump strainer structural assembly are given below. The figures illustrate the component analyzed.

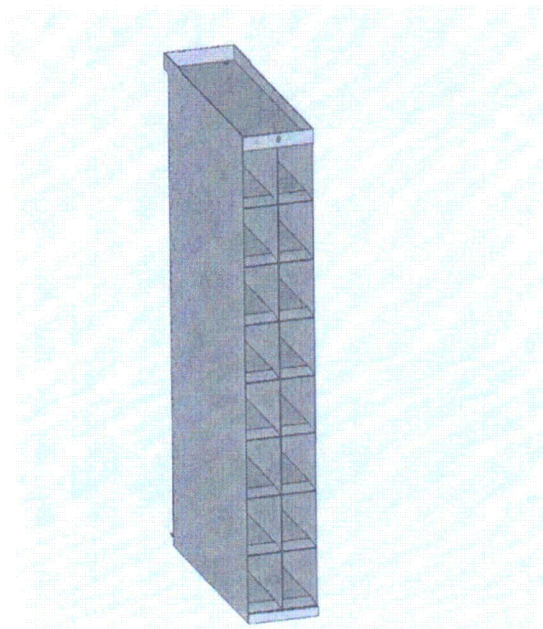

Figure 3k2-1
Cartridges

Table 3k2-1
Cartridges

Ratio	Allowable MPa	Calculated MPa	Stress Location and Type
1.337	306.9	410.6 0.8%	Sidewall global + local bending stress (Level C) Strain intensity for collapse load evaluations
0.116	122.8	14.3	Sidewall connection to coverplate shear stress
0.014	204.6	2.8	Sidewall connection to coverplate tension
0.563	252.8	142.4	Upper cover plate bearing stress (Level C)
0.515	122.8	63.3	Upper cover plate shear stress (Level C)
0.402	306.9	123.3	Upper cover plate bending stress (Level C)
1.002	252.8	253.0	Lower cover plate bearing stress (Level C)
1.554	306.9	476.9 1.6%	Cartridge pocket bending stress (Level C) Strain intensity for collapse load evaluations
0.035	204.6	7.2	Cartridge pocket tension stress
0.028	122.8	3.4	Cartridge pocket support clip shear stress

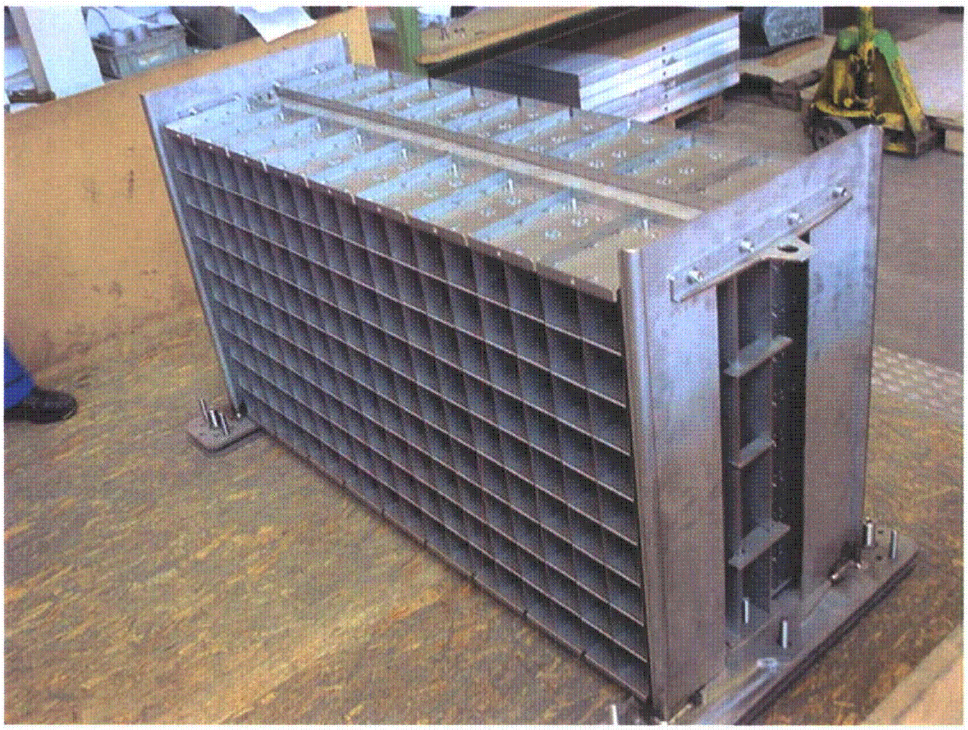

Figure 3k2-2
Standard Strainer Module

Table 3k2-2
Standard Module Support Structure

Ratio	Allowable MPa	Calculated MPa	Stress Location and Type
0.556	115.1	64	Maximum principle stress intensity – Load 1
0.759	259	196.6	Maximum principle stress intensity – Load 7
0.913	172.65	157.56	Maximum principle stress intensity – Load 8
0.116	259	30	Welded joints
0.023	279.77	6.56	M16 leveling screws compression stress
0.045	279.77	12.65	M20 leveling screws compression stress
0.426	239.04	101.9	M16 bolt membrane & bending stress
0.058	89.82	5.24	M16 bolt shear stress
0.013	92.68	1.21	M20 screws shear stress
0.005	246.64	1.2	M12 head screws normal stress – Load 7
0.005	92.68	0.48	M12 head screws shear stress – Load 7
0.349	59.88	20.9	Pin Ø 12/M8 screws shear stress
0.038	259.0	9.8	Closure plate of the duct bending
0.042	1515 lb_f	64.2 lb_f	Loads on anchorage – normal
0.030	3040 lb_f	92.55 lb_f	Loads on anchorage – shear

The bulk of the support structure is not loaded by the pressure differential created due to debris and chemical effects. However, the cartridge to duct cover and bottom are addressed in the cartridge section above. The module components are loaded by seismic effects including sloshing.

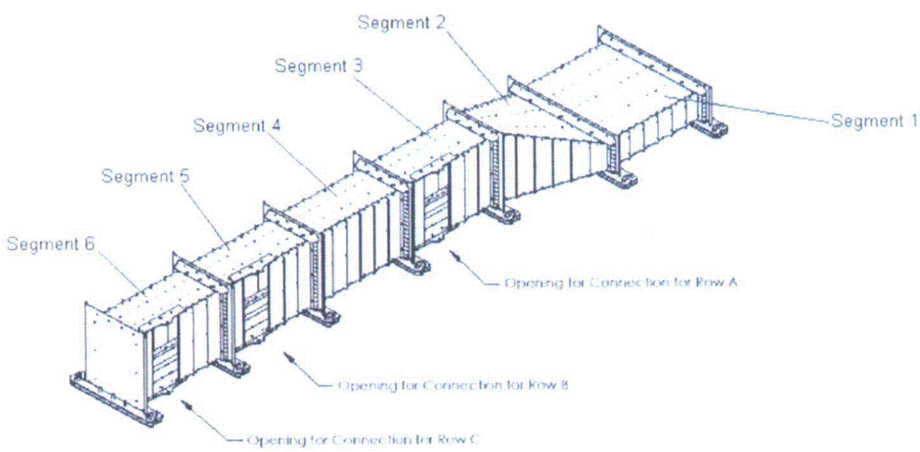

Figure 3k2-3
Radial Duct

Table 3k2-3
Radial Duct (nominal for all segments)

Ratio	Allowable MPa	Calculated MPa	Stress Location and Type
0.002	82.74	0.18	Global bending of duct shear stress – Load 8
0.109	206.85	0.7	Global & local bending of cover plate – Load 8
0.007	61.03	0.434	Sidewalls compression stress – Load 8
0.003	122.76	0.21	Global bending of duct shear stress – Load 7
0.003	124.11	0.43	Loads in horizontal directions shear stress – Load 7
0.002	306.9	0.67	Global bending due to Weight & Earthquakes - Load 7
0.109	306.9	33.3	Local & global bending of cover plate – Load 7
0.074	63.5	4.72	Membrane stress in compression – Load 7
0.052	71.9	3.76	Axial compression of the sidewalls – Load 7
1.11	306.9	340.3 1.2%	Global & local bending sidewalls – Load 7 (Level C) Strain intensity for collapse load evaluation
0.375	17.45	6.55	Inner duct walls – Load 7

The bending stress for the radial duct is above the Level C allowable stress. Plastic-elastic analysis demonstrates that the strain intensity is well below 2/3 of the collapse load and the permanent distortion of the side walls do not lead to loss of function of the duct segment.

Table 3k2-4
Analysis of Retaining Structure of Radial Duct Segment 4

Ratio	Allowable MPa	Calculated MPa	Stress Location and Type
0.002	239.04	0.7	Support plate w/anchorage M30/M16 tension
0.185	89.82	16.6	Support plate w/anchorage M30/M16 shear stress
0.019	92.7	1.8	Connection duct to retaining structure shear stress
0.012	246.64	3.0	Cylinder head screw M12 normal stress
0.024	92.68	2.2	Cylinder head screw M12 shear stress
0.360	259	93.14	Support legs membrane bending stress
0.018	103.6	1.83	Support legs shear stress
0.124	259	32.2	Closure plate of the duct bending stress
0.008	1515 lb_f	12.51 lb_f	Anchor plate w/4 Hilti Kwik Bolts 111 tension
0.096	3040 lb_f	292.5 lb_f	Anchor plate w/4 Hilti Kwik Bolts 111 shear

Table 3k2-5
Analysis of the Duct Structure of Radial Duct Segment 1

Ratio	Allowable MPa	Calculated MPa	Stress Location and Type
0.002	82.74	0.18	Global bending of duct shear stress
0.002	206.85	0.35	Global & local bending of cover plate
0.006	82.3	0.51	Sidewalls compression stress
0.001	122.76	0.17	Global bending of duct shear stress
0.001	122.8	0.13	Loads in horizontal directions shear stress
0.001	306.9	0.4	Global bending due to Weight & Earthquakes
0.389	306.9	119.4	Global and local bending of cover plate
0.082	23.7	1.94	Membrane stress in compression
0.089	100.6	9.0	Axial compression of the sidewalls
0.187	306.9	57.5	Global & local bending sidewalls
1.50 0.67	24.8 15.3 psi	37.3 10.2 psi	Inner duct walls (Level C) Level C Allowable Differential Pressure (NB-3228.3 of Reference 19)

The inner duct walls exhibit greater stress than that allowed for a Level C evaluation. However, an elastic-plastic analysis was performed. The actual differential pressure is well below 2/3 of the collapse differential pressure. Therefore, Segment 1 of the radial duct will not collapse and the radial duct will perform its function.

Table 3k2-6
Analysis of Retaining Structure of Radial Duct Segment 1

Ratio	Allowable MPa	Calculated MPa	Stress Location and Type
0.138	89.82	12.4	Support plate w/anchorage M30/M16 shear
0.014	92.68	1.32	Connection duct to retaining structure shear
0.012	246.64	2.95	Cylinder screw M12 normal stress
0.023	92.68	2.16	Cylinder screw M12 shear stress
0.116	259	30.0	Support legs membrane bending stress
0.013	103.6	1.37	Support legs shear stress
0.072	3040 lb_f	218.8 lb_f	Anchor plate w/4 Hilti Kwik Bolts 111 shear stress

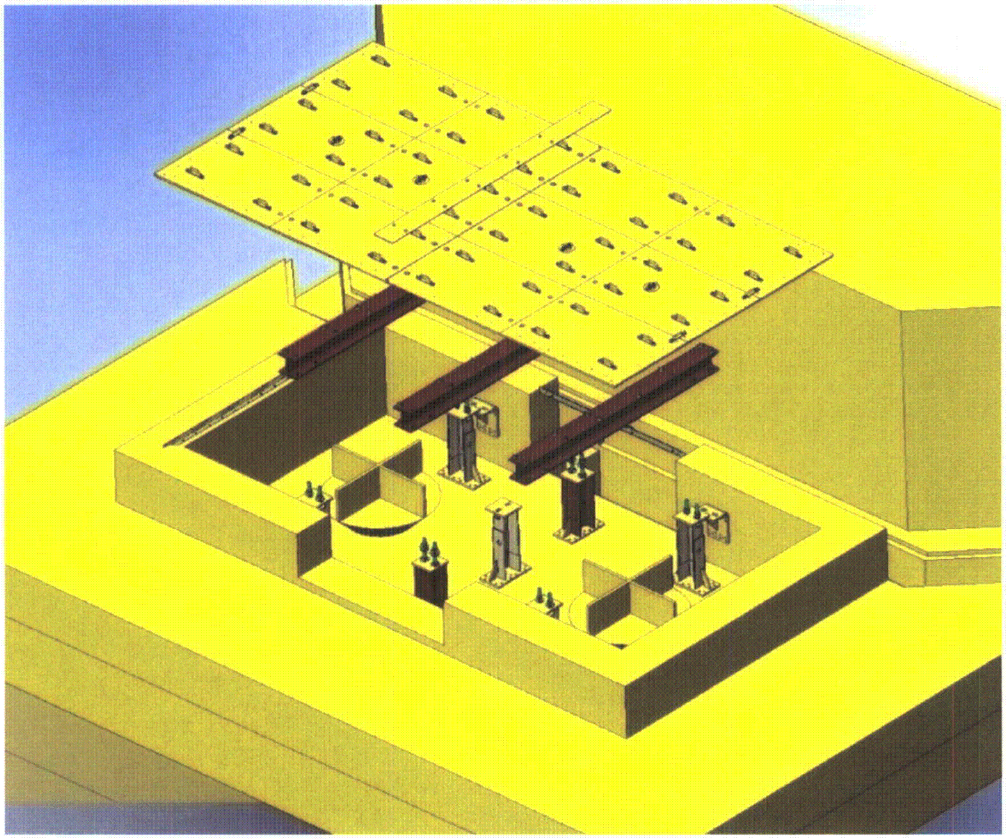

Figure 3k2-4
Sump Cover

Table 3k2-7
Sump Cover
(700 millibar differential pressure)

Ratio	Allowable	Calculated	Stress Location and Type
0.540	296.6 MPa	160.2 MPa	Cover plate bending stress
0.779	155.8 MPa	121.4 MPa	Stresses in support beam I-HEB140 (end beams)
0.153	94.7 MPa	14.5 MPa	Support columns bending stress
0.401	94.7 MPa	38.0 MPa	Support columns compression stress
0.534	N/A	N/A	Support columns combined bending and shear
0.182	383.6 MPa	69.9 MPa	Adjusting Bolts for mid beam (bending)
0.367	N/A	N/A	Adjusting Bolts for mid beam (combined compression, shear, and bending stress ratios)

Response to Issue 3k3:

Calvert Cliffs has approval to use leak-before-break methodology so that the dynamic effects of a LOCA do not need to be considered in the design of structures and components. Emergency Core Cooling System sump recirculation is not required for breaks in other piping systems.

Response to Issue 3k4:

The Calvert Cliffs ECCS sump strainer design does not incorporate a backflushing strategy.

NRC Issue 3l:

Upstream Effects

The objective of the upstream effects assessment is to evaluate the flowpaths upstream of the containment sump for holdup of inventory which could reduce flow to and possibly starve the sump. Therefore, provide a summary of the upstream effects evaluation including the information requested in GL 2004-02, "Requested Information," Item 2(d)(iv) including the basis for concluding that the water inventory required to ensure adequate ECCS or CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths.

1. *Summarize the evaluation of the flow paths from the postulated break locations and containment spray washdown to identify potential choke points in the flow field upstream of the sump.*
2. *Summarize measures taken to mitigate potential choke points.*
3. *Summarize the evaluation of water holdup at installed curbs and/or debris interceptors.*
4. *Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.*

Response to Issue 3l1:

The lower level of Containment is open and contains no compartment or choke point which could prevent water from flowing to the sump.

The flow path is water from the Containment Spray System is sprayed from the containment dome area and falls into the refueling canals. The canals then overflow to the reactor cavity since the drains are very small and assumed to be clogged with debris. The reactor cavity fills since it has a 4-inch drain that drains to the normal containment sump through a 2-inch drain line with a 2-inch valve that is also assumed to become clogged. The water spilling from the refueling canals flows down into the reactor cavity through the hatches or doors in the permanently installed seal between the reactor upper flange and the reactor cavity wall. Water is then postulated to enter the cavity cooling system. This is an air duct system. It has been shown that once water reaches a certain height, a portion of the ducting will collapse, releasing the water back to Containment. To provide a more conventional release point, a blowout panel will be installed in the cavity cooling duct supply to allow water in the duct work to spill back to the sump pool.

The containment water level calculation assumes all of these compartments are filled with water thereby reducing the predicted sump water height.

Response to Issue 3l2:

A drain cover is placed on the 1" drain line of the refueling pool compartment, but even if this drain does not clog, this size drain line is insufficient to prevent this compartment from filling up with water. The reactor cavity area is periodically inspected for debris, and the 4" drain line with the 2" outlet is of sufficient size to drain the water from the refueling pool cavity to the sump pool.

The only debris that could be generated in the refueling pool is reflective metal insulation which likely would not block the 4" reactor cavity drain in the event of a break near a reactor vessel nozzle. However, no inspection of the drain valve and piping is performed for personnel dose reasons. Therefore, this drain is assumed to be blocked. As discussed in 3l1, a blowout panel will be installed to ensure water that enters the cavity cooling piping is released back to the containment sump pool.

Response to Issue 3l3:

There are no curbs of sufficient dimension to impact water flow to the sump.

Response to Issue 3l4:

See the Response to Issue 3l1 above.

NRC Issue 3m:

Downstream effects - Components and Systems

The objective of the downstream effects, components and systems section is to evaluate the effects of debris carried downstream of the containment sump screen on the function of the ECCS and CSS in terms of potential wear of components and blockage of flow streams. Provide the information requested in GL 04-02, "Requested Information," Item 2(d)(v) and 2(d)(vi) regarding blockage, plugging, and wear at restrictions and close tolerance locations in the ECCS and CSS downstream of the sump. If approved methods were used (e.g., WCAP-16406-P), briefly summarize the application of the methods. The objective of the downstream effects, components and systems section is to evaluate the effects of debris carried downstream of the ECCS Sump screen on the function of the ECCS and CSS in terms of potential wear of components and blockage of flow streams. Provide the information requested in GL 04-02 Requested Information Item 2(d)(v) and 2(d)(vi) regarding blockage, plugging, and wear at restrictions and close tolerance locations in the ECCS and CSS downstream of the ECCS Sump.

GL 2004-02 Requested Information Item 2(d)(v)

The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the ECCS Sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the ECCS Sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.

GL 2004-02 Requested Information Item 2(d)(vi)

Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

3m1. If NRC-approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE) briefly summarize the application of the methods. Indicate where the approved methods were not used or exceptions were taken, and summarize the evaluation of those areas.

3m2. Provide a summary and conclusions of downstream evaluations.

3m3. Provide a summary of design or operational changes made as a result of downstream evaluations.

Response to Issue 3m1:

Reference 12 is used to evaluate the downstream components for the effects of plugging/erosion. All particulate (10 μm) debris is assumed to transport through the system, and not deplete over 30 days. The amount of fiber bypass is in accordance with Reference 12 with the appropriate bounding and conservative testing done to establish the strainer bypass fraction. The amount of fiber that transports through the system is computed to deplete with time in accordance with this WCAP.

Valves, pumps, heat exchanger tubes, orifices, containment spray nozzles were evaluated for plugging and erosion based on the concentrations and maximum particle size as determined by the Reference 12 methodology.

<u>Response to Issue 3m2</u>:

Testing of a replacement HPSI pump cyclone separator was performed by Wyle Labs in May and June 2008. The testing demonstrated that the selected replacement cyclone separator would not plug and would not erode sufficiently to defeat its function. Replacement of all HPSI pump cyclone separators with the tested unit was completed by June 30, 2008.

Evaluation of the HPSI and CS mechanical seals determined that testing was not needed.

Debris loads for the downstream analytical evaluations are based on bypass testing of the CCI strainer. The sump strainer opening consists of 1.6 mm (1/16") diameter holes. A post-installation examination inspects for gaps at all strainer interfaces/joints. The acceptance criterion is no gap greater than 1/32" can remain. These small openings will ensure no large particles enter the downstream recirculation piping.

All static piping components and valves were evaluated according to methods of Reference 12 as noted in Response to Issue 3m1 above.

Most piping components pass the evaluation criteria for plugging and wear. Those that did not pass the evaluation criteria were shown to have no adverse affect on component function.

<u>Response to Issue 3m3</u>:

No design or operational changes are anticipated as a result of Calvert Cliffs downstream effects evaluations.

***<u>NRC Issue 3n</u>*:**

Downstream Effects - Fuel and Vessel

The objective of the downstream effects, fuel and vessel section is to evaluate the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on core cooling.

1. *Show that the in-vessel effects evaluation is consistent with, or bounded by, the industry generic guidance (WCAP-16793), as modified by NRC staff comments on that document. Briefly summarize the application of the methods. Indicate where the WCAP methods were not used or exceptions were taken, and summarize the evaluation of those areas.*

<u>Response to Issue 3n1</u>:

Calvert Cliffs expects to demonstrate that in-vessel downstream effects are resolved by showing that Calvert Cliffs' plant conditions are bounded by the final WCAP-16793-NP and the corresponding NRC Safety Evaluation.

***<u>NRC Issue 3o</u>*:**

Chemical Effects

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling.

1. *Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at*

the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.

2. *Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML072600372).*

   2.1 *Sufficient 'Clean' Strainer Area: Those licensees performing a simplified chemical effects analysis should justify the use of this simplified approach by providing the amount of debris determined to reach the strainer, the amount of bare strainer area and how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed.*

   2.2 *Debris Bed Formation: Licensees should discuss why the debris from the break location selected for plant-specific head loss testing with chemical precipitate yields the maximum head loss. For example, plant X has break location 1 that would produce maximum head loss without consideration of chemical effects. However, break location 2, with chemical effects considered, produces greater head loss than break location 1. Therefore, the debris for head loss testing with chemical effects was based on break location 2.*

   2.3 *Plant Specific Materials and Buffers: Licensees should provide their assumptions (and basis for the assumptions) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects.*

   2.4 *Approach to Determine Chemical Source Term (Decision Point): Licensees should identify the vendor who performed plant-specific chemical effects testing.*

   2.5 *Separate Effects Decision (Decision Point): State which method of addressing plant-specific chemical effects is used.*

   2.6 *AECL Model: Since the NRC USNRC is not currently aware of the testing approach, the NRC USNRC expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results.*

   2.7 *AECL Model: Licensees should provide the chemical identities and amounts of predicted plant-specific precipitates.*

   2.8 *WCAP Base Model: For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart [in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425)], justify any deviations from the WCAP base model spreadsheet (i.e., any plant specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.*

   2.9 *WCAP Base Model: List the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.*

   2.10 *WCAP Refinements: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.*

   2.11 *Solubility of Phosphates, Silicates and Al Alloys: Licensees should clearly identify any refinements (plant-specific inputs) to the base WCAP-16530 model and justify why the plant-specific refinement is valid.*

   2.12 *Solubility of Phosphates, Silicates and Al Alloys: For crediting inhibition of aluminum that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminum, (2) the time needed to reach a phosphate or silicate level in the pool that would result in aluminum passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminum that is sprayed is assumed to be passivated.*

2.13 *Solubility of Phosphates, Silicates and Al Alloys: For any attempts to credit solubility (including performing integrated testing), licensees should provide the technical basis that supports extrapolating solubility test data to plant-specific conditions. In addition, licensees should indicate why the overall chemical effects evaluation remains conservative when crediting solubility given that small amount of chemical precipitate can produce significant increases in head loss.*

2.14 *Solubility of Phosphates, Silicates and Al Alloys: Licensees should list the type (e.g., AlOOH) and amount of predicted plant specific precipitates.*

2.15 *Precipitate Generation (Decision Point): State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.*

2.16 *Chemical Injection into the Loop: Licensees should provide the one-hour settled volume (e.g., 80 ml of 100 ml solution remained cloudy) for precipitate prepared with the same sequence as with the plant-specific, in-situ chemical injection.*

2.17 *Chemical Injection into the Loop: For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminum), the percentage that precipitates, and the percentage that remains dissolved during testing.*

2.18 *Chemical Injection into the Loop: Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100%, 140%).*

2.19 *Pre-Mix in Tank: Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530.*

2.20 *Technical Approach to Debris Transport (Decision Point): State whether near field settlement is credited or not.*

2.21 *Integrated Head Loss Test with Near-Field Settlement Credit: Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.*

2.22 *Integrated Head Loss Test with Near-Field Settlement Credit: Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.*

2.23 *Head Loss Testing Without Near Field Settlement Credit: Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.*

2.24 *Head Loss Testing Without Near Field Settlement Credit: Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).*

2.25 *Test Termination Criteria: Provide the test termination criteria.*

2.26 *Data Analysis: Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.*

2.27 *Data Analysis: Licensees should explain any extrapolation methods used for data analysis.*

2.28 *Integral Generation (Alion):*

2.29 *Tank Scaling / Bed Formation: Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values.*

2.30 *Tank Scaling / Bed Formation: Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.*

2.31 *Tank Transport: Explain how the transport of chemicals and debris in the testing facility is representative or conservative with regard to the expected flow and transport in the plant-specific conditions.*

2.32 *30-Day Integrated Head Loss Test: Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.*

2.33 *30-Day Integrated Head Loss Test: Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.*

2.34 *Data Analysis Bump Up Factor: Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.*

<u>Response to Issue 3o1</u>:

Debris and other containment sources which could contribute to the formation of chemical precipitates in the sump pool were evaluated using the methodology of Reference 22. The results of this calculation showed the elemental amounts of calcium (Ca), silicon (Si), and aluminum (Al) expected to be released into the sump pool as well as the expected quantities of precipitates: $Ca_3(PO_4)_2$, AlOOH, and $NaAlSi_3O_8$.

Head loss testing with chemical precipitates was originally conducted in November 2007. Inputs to the calculation which supported this test were based on accurate sources. However, actions have been taken to reduce these sources or mitigate their effect. For instance, the quantity of aluminum inside Containment was taken from the Updated Final Safety Analysis Report. A subsequent review (confirmed by walkdown during the 2008 refueling outage) shows that this quantity can be reduced by approximately 90% if aluminum scaffolding is removed from Containment. The scaffolding was removed from Unit 1 in 2008 and Unit 2 in 2009.

Testing was performed from October to December 2008 to demonstrate head loss across the strainer and debris bed. This testing included the appropriate chemical precipitates and especially the effects of aluminum reduction. The maximum head loss was 700 millibar (10.15 psi) for the STB buffer conditions. These conditions produce only aluminum-based precipitates assuming Reference 22 methodology. As discussed below, there is strong evidence that even aluminum-based precipitates will not form in the Calvert Cliffs sump pool.

The quantities of fibrous and particulate debris used in the testing were estimated prior to testing and found to be bounding when debris generation and transport calculations were completed later. The quantities of the precipitates mentioned above were estimated based on the estimated debris, water volume, spray duration, water temperature, exposed concrete, exposed aluminum, and water chemistry.

The testing relied upon to measure strainer head loss followed the general concepts of Reference 22 for aluminum based precipitates for the STB buffer material. The level of dissolved aluminum at Calvert Cliffs is low enough that no aluminum based precipitate effects are expected until the sump fluid temperature decreases to less than the nil-ductility temperature of the reactor vessel, based on testing performed by Alion. The aluminum based precipitates expected, if any are formed, are only sodium aluminum silicate ($NaAlSi_3O_8$). Sufficient silica is dissolved from insulation to ensure that no aluminum oxy-hydroxide (AlOOH) forms. However, based on ANL test results for AlOOH (Reference 29), Calvert Cliffs conservatively assumes that aluminum will precipitate out as sodium aluminum silicate and will begin to affect strainer head loss at sump pool temperatures between 140°F and 110°F.

Response to Issue 3o2.1:

Calvert Cliffs is not performing a simplified chemical effects analysis.

Response to Issue 3o2.2:

The head loss results when chemical precipitates were included were nearly 90 times greater than that when only fiber and particulate were included. It was recognized that the break location having the greatest chemical precipitate load must be identified. The chemical precipitate debris loads for various break locations were computed to identify the worst-case chemical precipitate load. This computation is based on inputs for the following:

1. Metallic aluminum
2. Calcium-silicate
3. E-glass
4. Mineral wool
5. Concrete

The inputs for items 1 and 5 are the same regardless of the break location. The input for item 2 is break location-dependent; however, the results from the break which generated the most calcium-silicate were used in evaluating all potential break locations. Items 3 and 4 are insulation debris loads and are break-location dependent. More mass of these insulation items results in increased production of chemical precipitates. A given mass of mineral wool generates more aluminum-based precipitates than the same mass of E-glass. This was considered when evaluating which break location provided the worst-case debris load.

Thin bed effects were investigated by using low quantities of the postulated fibrous debris and the entire particulate loading to verify that the CCI strainer does not produce a thin bed effect for the debris from Calvert Cliffs. This also ensures that a break that produces little debris does not produce an unexpectedly high head loss.

Response to Issue 3o2.3:

The following assumptions or results of calculations were used to determine the chemical effects loading used in testing:

- pH = 7.75 for testing related to sodium tetraborate conditions (determined by chemical modeling for the maximum pH condition with the new buffer).
- Temperature of containment sprays, sump water, and containment gas volume are based on a recent containment accident analysis which shows the maximum sump water temperature to be about 275°F and the maximum sump water temperature at the start of recirculation to be about 219°F (noted in Response to Issue 3g1).
- Continuous containment spray.
- Total quantity of water (both minimum and maximum possible as determined by calculation).
- Materials in Containment considered in the calculation of chemical effects precipitate with quantity of each as determined in calculations.
    - Aluminum metal exposed to sprays and submerged
    - Fibrous debris, especially E-glass and mineral wool
    - Exposed concrete
    - Calcium silicate from Marinite boards
- No head loss due to aluminum-based precipitates until a temperature below 140°F.

Response to Issue 3o2.4:

CCI performed quality-assured chemical effects testing for Calvert Cliffs.

Response to Issue 3o2.5:

The plant-specific chemical effects were assessed by test. The methods of Reference 22 were used to assess the plant specific chemical effects precipitate loading and testing. Chemical precipitates were produced using the methods of Reference 22. A debris bed of fibrous and particulate debris was developed by adding debris to the test flume where the strainer captured and retained the bulk of the debris. Precipitates were added after the debris bed was formed.

Response to Issue 3o2.6:

Calvert Cliffs did not use an AECL model.

Response to Issue 3o2.7:

Calvert Cliffs did not use an AECL model.

Response to Issue 3o2.8:

Calvert Cliffs did not deviate from the WCAP base model spreadsheet.

Response to Issue 3o2.9:

The predicted amount of plant-specific precipitates is provided in the table below.

Table 3o2.9-1
Table of Base Model Chemical Precipitates for Calvert Cliffs

Precipitate	Quantity for STB Buffer
$Ca_3(PO_4)_2$ (calcium phosphate)	0 lbs
$NaAlSi_3O_8$ (sodium aluminum silicate)	335.2 lbs
AlOOH (aluminum oxy-hydroxide)	0 lbs

Response to Issue 3o2.10:

Calvert Cliffs utilizes one refinement to the methods of WCAP-16530-NP-A (Reference 22). The effect of aluminum based precipitates on head loss is delayed based on the temperature at which the aluminum based precipitates would be expected to begin forming. Calvert Cliffs considers three potential precipitates: calcium phosphate, sodium aluminum silicate, and aluminum oxy-hydroxide. Because Calvert Cliffs is a STB buffered plant, the lack of TSP eliminates consideration of calcium phosphate and limits consideration to the potential aluminum precipitates.

Calvert Cliffs performed chemical head loss testing with plant-specific chemistry to investigate the head loss impact of aluminum precipitates. This testing was performed with aluminum concentrations from 5 ppm to 70 ppm and silicon concentrations from 0 ppm to 220 ppm which would allow any aluminum precipitate to form that could form in the chemical environment. This Calvert Cliffs-specific testing program included test durations ranging from 60 to 100 hours an identified no precipitate-based head loss impact for the entire temperature range down to 60°F. (see Enclosure 1)

Liquid samples were extracted from the test loop during the tests and analyzed for element content using inductively Coupled Plasma Spectroscopy (ICP). No reduction in aluminum or silicon concentration was identified indicating that either no precipitates formed or, if precipitates did form, they were not captured in the debris bed. The debris bed was verified as a sensitive instrument for detecting precipitate-based head loss through a test using pre-made aluminum precipitates.

Argonne National Laboratory (ANL) head loss testing documented in NUREG/CR-6913 also showed no chemical precipitates based head loss until aluminum concentrations were raised above 50 ppm and test duration prior to precipitation detection of 20 days or more. Argonne National Laboratory solubility correlations suggest that the AlOOH might begin to precipitate at temperatures as high as 140°F; however ANL experimental vertical loop head loss data confirmed at such AlOOH precipitation with STB buffer only caused head losses at aluminum concentrations between 50 ppm and 100 ppm, more than five times the aluminum levels found in Calvert Cliffs post-LOCA containment sump. As stated above, Calvert Cliffs specific testing found no head loss from either AlOOH or sodium-aluminum silicate for Calvert Cliffs chemical conditions and temperatures as low at 60°F.

Although Enclosure 1 presents a conservative technical basis for acceptance of chemical effects on strainer head loss at temperatures no higher than 110°F, Calvert Cliffs has also evaluated chemical effects on strainer head loss at temperatures up to 140°F (see Response to Issue 3g16). The upper end of the temperature range was chosen because it matches previously accepted temperatures for chemical effects on head loss for other power plants. Note that the buffer used in the ANL testing is not identical to that used at Calvert Cliffs and the precipitate that ANL saw (AlOOH) is not expected to be seen at Calvert Cliffs.

Response to Issue 3o2.11:

There were no refinements used.

Response to Issue 3o2.12:

Inhibition or passivation of aluminum was not used in determining aluminum corrosion and the resultant chemical precipitates.

Response to Issue 3o2.13:

No reduction of chemical precipitates was achieved by crediting solubility. The timing of the effect of chemical precipitates is based on solubility, especially for sodium aluminum silicate. Although testing by Alion (using Calvert Cliffs-specific data) showed no aluminum based precipitate effects down to 65°F, Calvert Cliffs conservatively assumes aluminum based precipitates form as sodium aluminum silicate and affect head loss below temperatures between 140°F and 110°F.

Response to Issue 3o2.14:

See the table in Response to Issue 3o2.9.

Response to Issue 3o2.15:

Precipitates are formed in a separate mixing tank.

Response to Issue 3o2.16:

Precipitates were not formed by injection into the test loop.

Response to Issue 3o2.17:

Precipitates were not formed by injection into the test loop.

Response to Issue 3o2.18:

Precipitates were not formed by injection into the test loop.

Response to Issue 3o2.19:

No exceptions to the procedures of Reference 22 were taken.

Response to Issue 3o2.20:

Credit for near-field settlement in the plant is not taken. Debris and chemical precipitates in the tests were transported to the strainer and lodged in the strainer pockets, on the face of the strainer, or at the base of the strainer. The debris found at the base of the strainer could not be made to enter the strainer pockets even with mechanical agitation. This debris behavior was observed and could not be eliminated. All credited tests demonstrated repeatability. Similar quantities of debris at the base of the strainer under test were observed in all tests.

Near-field settlement of chemical precipitates was not credited in the tests. Chemical precipitates accumulated on the fibrous debris in all locations similar to the accumulation on the debris bed captured by the strainer.

Response to Issue 3o2.21:

See the Response to Issue 3o2.24 below for the one-hour settlement values of the chemical precipitates.

Response to Issue 3o2.22:

No chemical precipitate settled away from the strainer. Some chemical precipitate surrogate was found on the fibrous debris immediately in front of the test strainer. No separate estimate of chemical precipitates at any location was provided in the test report from CCI. However, their overall estimates for all debris, including precipitates, was 20-35% settled immediately adjacent to the strainer. A reasonable assumption is that the chemical precipitates surrogate distributed in the same proportion as the other debris.

Response to Issue 3o2.23:

CCI estimated that about 20-35% of the debris was found immediately adjacent to the strainer supported by the flume floor in design basis tests of October - December 2008.

The strainer pockets were full of fibrous and particulate debris and a six inch plus debris bed had formed on the outside of the strainer immediately prior to chemical precipitate addition. Agitation was unable to move more debris into the strainer pockets because of the low flow rates at and into the strainer. The strainer face flow speed is about 0.002 feet per second and the approach speed for the strainer as it transitions to a more simple shape once it is full is about 0.02 feet per second. Neither flow speed is adequate to maintain debris in suspension for long. Debris that does not get into the pockets during initial loading and subsequent agitation cannot move into pockets later.

The strainer pockets generally were full of fibrous debris and chemical precipitates at the end of the tests. Increased head loss due to the chemical precipitates may have created boreholes during testing as evidenced by sudden head loss decreases. (Calvert Cliffs takes no credit for viscosity or temperature corrections in determining head loss as noted in Response to Issue 3f13.) However, the increase in head loss did not appear to significantly compress the debris filling the strainer pockets.

Response to Issue 3o2.24:

One hour precipitate settling for the quality-assured tests is provided in the table below. The settling tests were performed immediately before precipitate addition to the test flume.

Table 3o2.24-1
Base Model Chemical Precipitates Settled Volume for Calvert Cliffs

Precipitate	**Settled Volume Quantity for Test 6 Chemical Precipitates**	**Settled Volume Quantity for Test 7 Chemical Precipitates**
$Ca_3(PO_4)_2$ (calcium phosphate)	N/A	N/A
$NaAlSi_3O_8$ (sodium aluminum silicate)	98%	97%
AlOOH (aluminum oxy-hydroxide)	N/A	N/A

Response to Issue 3o2.25:

The quality-assured tests were terminated by test director discretion. As can be seen in the figure in Response to Issue 3o2.26, the head loss across the strainer and debris bed at termination was substantially less than the peak head loss. Furthermore, the head loss generally was decreasing but unsteadily. No further test effects were planned. No effects were expected which would cause the head loss to begin to generally increase.

Response to Issue 3o2.26:

The results of the valid Calvert Cliffs head loss testing are presented below. These three tests were performed at CCI in November and December 2008, using methods described in Response to Issue 3f4.

The maximum head loss observed was nearly 700 millibar (Figure 3o2.26-1) and is used as the design head loss across the strainer for debris laden conditions, including chemical effects. Initial flow rates are nearly seven times the nominal and provide a clear basis supporting no vortex formation. (see Response to Issue 3f3) Flow sweeps were performed at the conclusion of the test to demonstrate stability of the bed.

Note that recent aluminum solubility test results, which show no aluminum based precipitates are expected to impact head loss for Calvert Cliffs, provide for much reduced chemical effects and hence much lower head losses. However, based on results provided by testing completed at Argonne National Laboratory (Enclosure 1), Calvert Cliffs assumes aluminum precipitates in the form of sodium aluminum silicate will form and affect head loss below temperatures between 140°F and 110°F. Therefore, the testing performed at CCI with the chemical precipitate quantity predicted by WCAP-16530-NP-A methods is highly conservative, compared with the expected outcome (no precipitate effect above 65°F).

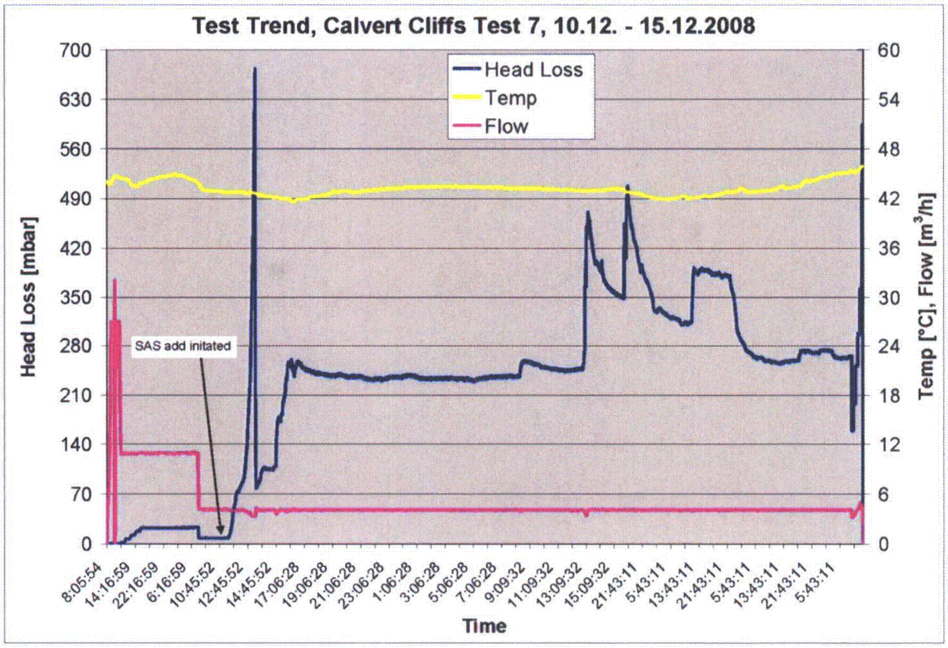

Figure 3o2.26-1
Head Loss Test Results - Test 7, December 2008

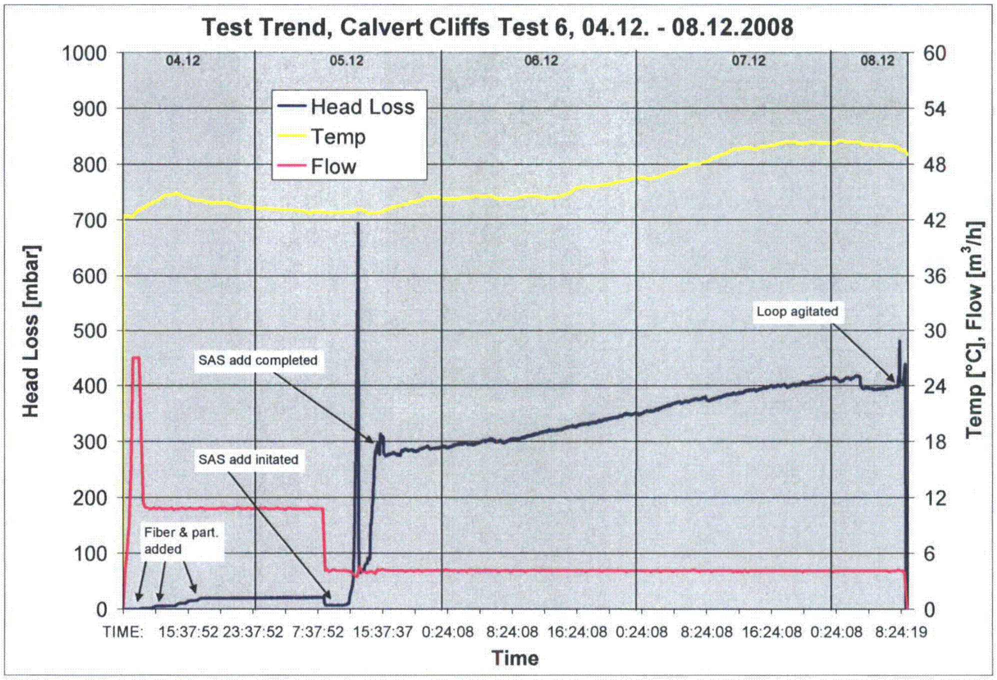

Figure 3o2.26-2
Head Loss Test Results - Test 6, December 2008

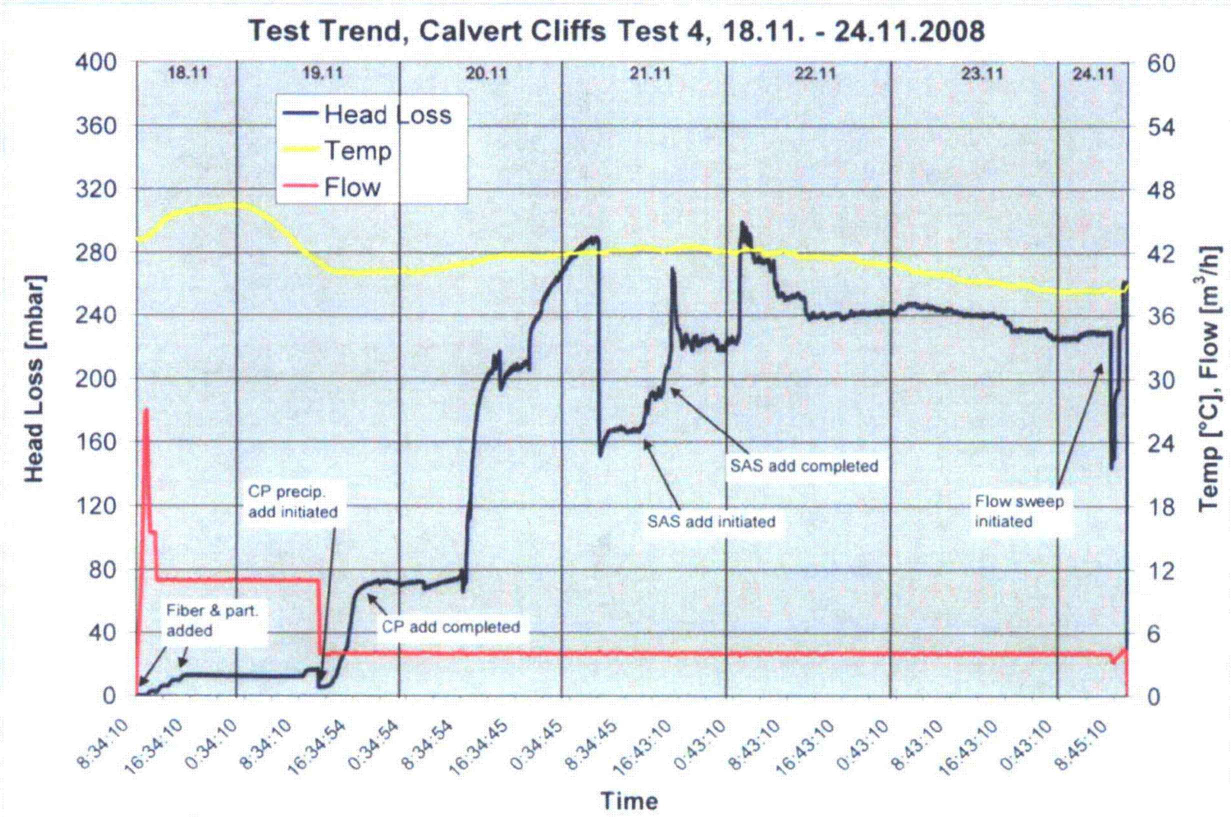

Figure 3o2.26-3
Head Loss Test Results - Test 4, November 2008

The tests concluded with a flow sweep where the flow was varied in discreet steps from 80% to 120% of the nominal design flow rate. These variations were performed to investigate the following:

- The effect that flow fluctuations would have on the stability of the debris bed formed on the strainer, and
- The effect flow speed variations would have on the head losses across the strainer and debris.

For Test 7 (Figure 3o2.26-1), at the far right of the figure, one can see the flow variations and the resultant head losses due to the flow sweeps. Prior to the start of the flow sweeps, the head loss across the strainer and debris was about 262 millibar. When the flow was restored to 100% of the design flow during the flow sweep, the head loss was about 252 millibar. Such behavior indicates that the debris bed was stable and was not easily disturbed by flow fluctuations. At a flow rate of 120% of design rate, the head loss was about 360 millibar or about 37% greater than the head loss at the design flow rate. This change is generally consistent with turbulent flow head loss theory where head loss is proportional to the square of the flow speed: increase flow by 20% and achieve 44% increase in head loss (120% x 120% = 144%).

Response to Issue 3o2.27:

Calvert Cliffs uses no data extrapolation methods. Calvert Cliffs uses area-based scaling between the test and the plant design for debris quantities, chemical precipitate quantities, and flow rate through the strainer. Calculations dependent on head loss testing use the head loss test results without modification.

The scaled test parameters were bounding on the containment sump strainer especially for debris loading and flow.

Response to Issue 3o2.28:

Calvert Cliffs did not perform Alion style testing.

Response to Issue 3o2.29:

Calvert Cliffs did not perform Alion style testing.

Response to Issue 3o2.30:

Calvert Cliffs did not perform Alion style testing.

Response to Issue 3o2.31:

Calvert Cliffs did not perform Alion style testing.

Response to Issue 3o2.32:

Calvert Cliffs did not perform Alion style testing.

Response to Issue 3o2.33:

Calvert Cliffs did not perform Alion style testing.

Response to Issue 3o2.34:

Calvert Cliffs did not perform Alion style testing.

***NRC Issue 3p*:**

Licensing Basis

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the sump evaluation or plant modifications. Provide the information requested in GL 04-02, "Requested Information," Item 2(e) regarding changes to the plant licensing basis. That is, provide a general description of and planned schedule for any changes to the plant licensing bases resulting from any analysis or plant modifications made to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. Any licensing actions or exemption requests needed to support changes to the plant licensing basis should be included. The effective date for changes to the licensing basis should be specified. This date should correspond to that specified in the 10 CFR 50.59 evaluation for the change to the licensing basis.

Response to Issue 3p:

The Calvert Cliffs licensing basis will be updated in accordance with the requirements of 10 CFR 50.71 to reflect the results of the analyses and the modifications performed to demonstrate compliance with the regulatory requirements. Calvert Cliffs received a license amendment for changing the containment buffer material from trisodium phosphate to sodium tetraborate (Reference 30).

REFERENCES:

(1) Not used

(2) Not used

(3) Not used

(4) Not used

(5) WCAP-16710-P, Revision 0, dated October 2007, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON Insulation at Wolf Creek and Callaway Nuclear Operating Plants"

(6) WCAP-16720-P, Revision 0, dated March 2007, "Jet Impingement Testing to Determine the Zones of Influence for Diablo Canyon Power Plant"

(7) WCAP-16568-P, Revision 0, dated June 2006, "Jet Impingement Testing to Determine the Zones of Influence (ZOIs) for DBA-Qualified/Acceptable Coatings"

(8) SL-009195, Revision 0, dated November 9 2007, "Wyle Jet Impingement Testing Data Evaluation"

(9) NUREG/CR-6808, dated February 2003, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance"

(10) NEI 04-07, Revision 0, December 2004, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Volume 1 and Volume 2

(11) Keeler & Long PPG Report No. 06-0413

(12) WCAP-16406-P, Revision 1, dated August 2007, Evaluation of Downstream Debris Effects in Support of GSI-191 with associated NRC SER dated December 20, 2007, ML073480324

(13) NEI 02-01, April 2002, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments"

(14) NUREG/CR-6916, dated December 2006, "Hydraulic Transport of Coating Debris"

(15) I. E. Idlechik, "Flow Resistance, a Design Guide for Engineers"

(16) NUREG/CR-6224, dated April 2005, "Correlation and Deaeration Software Package"

(17) Letter from Mr. C. H. Cruse (CCNPP) to Document Control Desk (NRC), dated November 13, 1998, Response to Generic Letter 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Deficiencies and Foreign Material in Containment"

(18) ASME Section III, Subsection NF, "Supports"

(19) ASME B&PVC Section III, Division I, Subsection N, "Supports," 2004 Edition including 2005 Addenda

(20) ASME B&PVC Section II, Part D, "Properties," 2004 Edition including 2005 Addenda

(21) Not used

(22) WCAP-16530-NP, Revision A, dated March 2008, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Supports GSI-191"

(23) Not used

(24) Letter from Mr. J. A. Spina (CCNPP) to Document Control Desk (NRC), dated June 18, 2008, Request for Extension for Completion of Activities Related to Generic Letter 2004-02

(25) Letter from Mr. D. V. Pickett (NRC) to Mr. J. A. Spina (CCNPP), dated June 30, 2008, Extension for Completion of Activities Related to Generic Letter 2004-02

(26) Not used

(27) Not used

(28) Not used

(29) Argonne National Laboratory Report dated September 19, 2008, "Aluminum Solubility in Boron Containing Solutions as a Function of pH and Temperature"

(30) Letter from Mr. D. V. Pickett (NRC) to Mr. J. A. Spina (CCNPP), dated March 4, 2009, Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 And 2 - Amendment Re: Replacement of the Trisodium Phosphate Buffer with a Sodium Tetraborate Buffer

(31) Not used

(32) Regulatory Guide 1.82, Revision 3, Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident, November 2003

ENCLOSURE (1)

Aluminum Precipitate Head Loss Considerations

ALION
SCIENCE AND TECHNOLOGY

TECHNICAL DOCUMENT COVER PAGE

Document No: **ALION-RPT-CCNPP-7651-001**	Revision: 1	Page 1 of 28
Document Title: **Aluminum Precipitate Head Loss Considerations at the Cliffs Nuclear Power Plant**		
Project No: 261-7651		
Project Name: **Aluminum Solubility Technical Report**		
Client: **Constellation Energy Calvert Cliffs Nuclear Power Plant, Inc.**		

Document Purpose/Summary:

The purpose of this technical report is to document the head loss considerations for aluminum precipitates as applicable to the Calvert Cliffs Nuclear Power Plant (CCNPP) containment recirculation sump strainer.

This report is prepared in accordance with the Alion ITSO Quality Assurance Program.

This document contains 45 pages including Appendixes.

Design Verification Method:

_X_ Design Review

___ Alternative Calculation

___ Qualification Testing

Professional Engineer (if required) Approval: Not Applicable Date

	Printed/Typed Name	Signature	Date
Prepared By:	Craig D. Sellers	[signature]	10.15.09
Reviewed By:	Jong-Hee Park, Ph.D	Jong Hee Park	10/15/2009
Approved By:	Craig D. Sellers	[signature]	10.15.09

Form 3.3.1
Revision 2
Effective Date: 2/28/07

ALION
SCIENCE AND TECHNOLOGY

REVISION HISTORY LOG

Document Number: **ALION-RPT-CCNPP-7651-001** Revision: 1

Document Title: **Aluminum Precipitate Head Loss Considerations at the Cliffs Nuclear Power Plant**

Instructions:
Project Manager to provide a brief description of each document revision, including rationale for the change and, if applicable, identification of source documents used for the change.

REVISION	DATE	Description
0	10/8/2009	Initial Issue
1	See Cover Page	Address Owners Acceptance Review Comments

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ACRONYMS AND DEFINITIONS

AlOOH	Aluminum Oxy-hydroxide
ANL	Argonne National Laboratory
CCNPP	Calvert Cliffs Nuclear Power Plant
ICET	Integrated Chemical Effects Test
LOCA	Loss of Coolant Accident
NaTB	Sodium Tetraborate
NAS	Sodium Aluminum Silicate
NRC	Nuclear Regulatory Commission
pH	Negative log of the hydrogen ion concentration
ppm	Parts per million

1.0 INTRODUCTION

Calvert Cliffs Nuclear Power Plant (CCNPP) prototype strainer head loss testing [Ref. 8.1] and vertical loop testing [Ref. 8.2], both conducted using Sodium Aluminum Silicate (NAS) precipitate produced in accordance with WCAP-16530 [Ref. 8.3 through 8.9], resulted in large chemical effects head loss. However, CCNPP vertical loop testing [Ref. 8.2] conducted with potential in-situ formation of aluminum precipitates resulted in no significant head loss. The purpose of this report is to present the technical information available regarding head loss effects of aluminum precipitates as applicable to CCNPP sump conditions, and based on this review, to provide a technical basis for a temperature-based application of chemical effects head loss in the evaluation of CCNPP recirculation sump performance.

1.1 Summary of Issue

As stated above, CCNPP prototype strainer head loss testing with aluminum precipitates produced in accordance with WCAP-16530 resulted in large chemical effects head loss. However, CCNPP vertical loop testing conducted with potential in-situ formation of aluminum precipitates resulted in no significant head loss.

1) CCNPP used the conservative WCAP-16530 methodology to determine the chemical precipitate debris source term.

2) The CCNPP sump fluid chemistry contains a high concentration of dissolved silicon and a small concentration of dissolved aluminum due to the large quantity of fibrous insulation and small quantity of structural aluminum in containment. This chemistry favors the formation of sodium aluminum silicate (NAS) and not aluminum oxy-hydroxide (AlOOH) based on the WCAP-16530 methodology.

3) Available data on aluminum and silicon dissolved in Sodium Tetraborate (NaTB) buffered solutions at CCNPP conditions shows no head loss impact due to potential aluminum precipitation between 135°F and 60°F for aluminum concentrations as high as 60 ppm.

4) If aluminum does precipitate under these CCNPP conditions, it does so in a form that does not cause significant head loss.

5) Argonne National Laboratory data on AlOOH solubility has recently been provided by the NRC. While this data is not directly applicable to the sump chemistry at CCNPP (it is for a low-silicon concentration environment), nonetheless it will be considered in this assessment.

6) The testing performed at Argonne that formed the basis for this aluminum solubility data was based on elemental analysis and visual observation of precipitation at aluminum concentrations between 40 and 98 ppm and head loss increases at aluminum concentrations greater than 100 ppm. The extrapolation of ANL aluminum solubility correlations to the conditions of the post-LOCA sump at CCNPP, which contains less than 10 ppm dissolved aluminum, involves the application of an empirical correlation to conditions that are not bounded by the body of ANL empirical evidence used to derive the correlation.

Based on these considerations, a conservative approach for addressing chemical effects on CCNPP sump performance will be presented that defines a temperature criterion above which it can be assumed that no chemical effects will occur, but below which they will be considered. Finally, conservatisms in this approach are summarized.

1.2 Calvert Cliffs Sump Chemistry

CCNPP uses NaTB as the containment sump buffer. The post-accident sump pH ranges from 7.0 to 7.6 [Ref. 8.10]. Using the WCAP-16530 methodology [Ref. 8.3 through 8.9], the aluminum concentration after 30 days ranges between 7.2 ppm to 2.6 ppm depending upon sump temperature, pH, and water volume. The NAS quantity used during strainer qualification testing was determined using a conservatively high pH of 7.75 which is higher than any pH prediction for CCNPP [Ref. 8.11].

2.0 CALVERT CLIFFS CONSERVATIVE ALUMINUM DISSOLUTION RATE

CCNPP used the conservative WCAP-16530 methodology to determine chemical precipitate debris source term. The WCAP-16530 methodology was used with a conservatively high pH. No refinements to this methodology, such as corrosion inhibition, were used.

Alion performed bench-top dissolution tests of aluminum in a borated water solution buffered to a pH of 8.3 with NaTB, with and without NUKON (fiberglass insulation) [Ref. 8.12]. Results are shown below and compared to WCAP-16530 prediction of aluminum release rate under the same conditions.

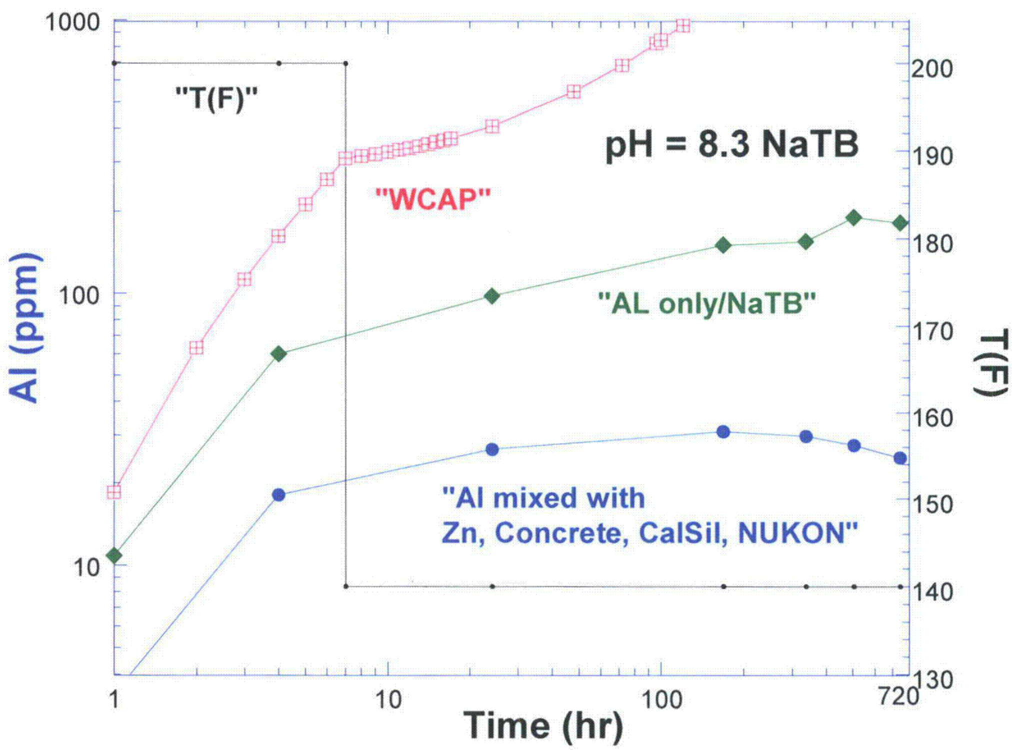


Figure 1: Aluminum Corrosion Test with and without NUKON
Alion Measured Aluminum Corrosion vs. WCAP-16530 Predicted Aluminum Corrosion

The WCAP aluminum dissolution rate is shown to be consistently and significantly greater than the aluminum dissolution rate observed in these tests.

The WCAP-16530 prediction of aluminum released amount shown in Figure 1 was calculated using the WCAP spreadsheet and the bench-top test conditions. These conditions include 53.4 cm^2 of aluminum in 350ml of a NaTB buffered solution at a pH of 8.3 maintained at 200°F for 7 hours followed by 140°F for the remainder of the 30 day test. These test conditions do not simulate CCNPP sump conditions but they are reasonably similar. This bench-top test was not performed for CCNPP.

The WCAP spreadsheet results are presented in Appendix 1.

3.0 CALVERT CLIFFS SUMP CHEMISTRY

In the CCNPP post-LOCA containment sump, dissolved silicon and aluminum are both present. Per the WCAP-16530 methodology, when dissolved silicon and aluminum are present in a borated aqueous environment, NAS is preferentially formed instead of AlOOH. If there is more than a 3.12:1 mass ratio of dissolved silicon to dissolved aluminum [Ref. 8.3], the aluminum-based chemical precipitate formed is NAS. Aluminum oxyhydroxide is not formed in the post-LOCA sump until depletion of the available silicon.

3.1 Sources of Dissolved Aluminum and Silicon

The nominal distribution of sources for aluminum and silicon species is summarized in Table 1.

Table 1: CCNPP Dissolved Aluminum and Silicon

Source Material	Al	Si
Metallic Aluminum %	10.5%	-
Fiberglass Insulation %	15.3%	83.8%
Mineral Wool Insulation %	74.0%	13.3%
Concrete %	<1%	<1%
Marinite Board %	-	2.4%
Total Concentration (ppm)	7.2	60.9

No high energy line breaks can be postulated in accordance with NRC approved guidance at CCNPP that could result in substantially different debris ratios [Ref. 8.13]. Specifically, no large break LOCA could produce a large quantity of Mineral Wool insulation without also producing a large quantity of Fiberglass insulation. Therefore, for all postulated large break scenarios, a much larger concentration of dissolved silicon than dissolved aluminum will be present in the sump fluid.

3.2 Bounding Chemistry Evaluations

Bounding containment sump chemistry evaluations were performed using the WCAP-16530 methodology spreadsheets. These evaluations determine the concentrations of aluminum, silicon, and NAS as a function of time. The evaluations were analyzed for four (4) bounding conditions;

1. Maximum Sump Water Volume (minimum sump pH) and Maximum Sump Water Temperature
   a. This case maximizes temperature-based corrosion rates while minimizing pH based aluminum solubility

2. Maximum Sump Water Volume (minimum sump pH) and Minimum Sump Water Temperature
   a. This case minimizes temperature-based corrosion rates while minimizing both temperature- and pH-based aluminum solubility

3. Minimum Sump Water Volume (maximum sump pH) and Maximum Sump Water Temperature
   a. This case maximizes temperature- and pH-based corrosion rates and aluminum solubility

4. Minimum Sump Water Volume (maximum sump pH) and Minimum Sump Water Temperature
   a. This case maximizes pH-based corrosion rates and minimizes temperature-based aluminum solubility

The containment temperature profiles available in CCNPP design calculations are developed to support containment response analysis. These temperature profiles are developed using conservative assumptions that tend to maximize temperatures. The solubility of aluminum precipitates is a function of temperature and is maximized at high temperature and minimized at lower temperature. Therefore, the use of temperature profiles using conservative assumptions that tend to maximize temperatures is not necessarily conservative when considering the head loss consideration of aluminum precipitates.

A low containment temperature profile was developed based on an assumed more rapid cool down from peak accident conditions is the containment response analysis. The containment response analysis and the assumed low containment temperature profile are provided in Appendix 2.

Sump pH is assumed to be initially 4.5. This pH is assumed to increase due to the dissolution of NaTB until a maximum pH of 7.75 is achieved [Ref. 8.14 (Attachment 3)]. Ref. 8.14 refers to a maximum pH of 7.6; therefore using an assumed pH of 7.75 is conservative. After that time, the maximum sump pH profile is assumed to drop to a pH of 7.5 due to the production of Nitric acid and Hydrochloric acid due to the radiologic decomposition of water and degradation of electrical cables.

The minimum sump pH is assumed to begin at 4.5, increase to a pH of 7.2 due to the dissolution of NaTB and then drop to a pH of 7.0 due to the production of Nitric acid and Hydrochloric acid due to the radiologic decomposition of water and degradation of electrical cables. A pH of 7.0 is the design basis minimum sump pH after dissolution of the containment sump buffer and production of the radiolytic acids.

The total dissolved aluminum and silicon, as well as the contribution from each source materials for the four bounding cases of sump chemistry are presented in Figure 2 through Figure 5. The WCAP spreadsheets used to develop these results are presented in Appendix 3.

As can be seen from these figures, in all cases, dissolved silicon is produced at a much greater rate than dissolved aluminum, and the silicon to aluminum mass ratio is greater than 3.12. From these results, the WCAP-16530 methodology would predict preferential formation of NAS over AlOOH.

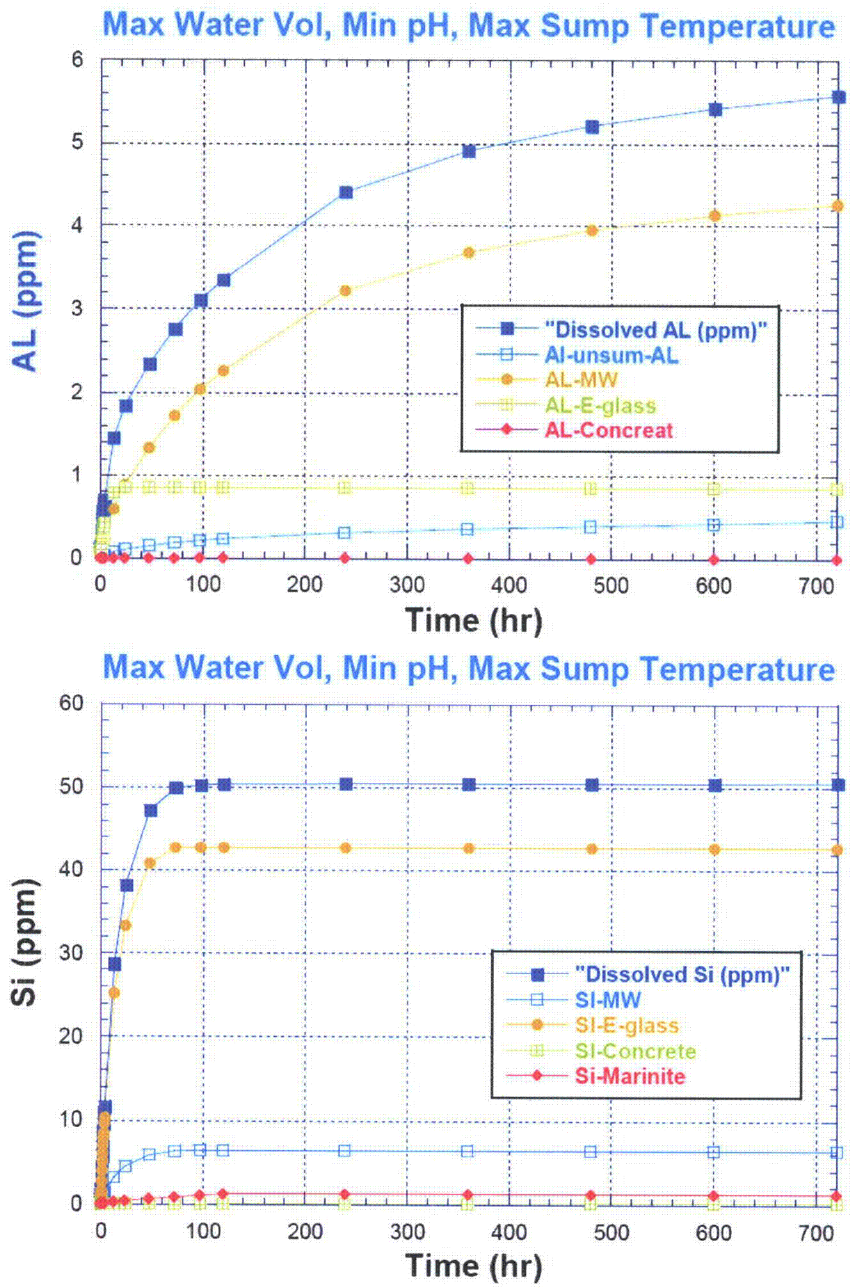


Figure 2: WCAP-16530 CCNPP Aluminum and Silicon Concentrations from various sources – Maximum Water Volume, Minimum pH, Maximum Sump Temperature

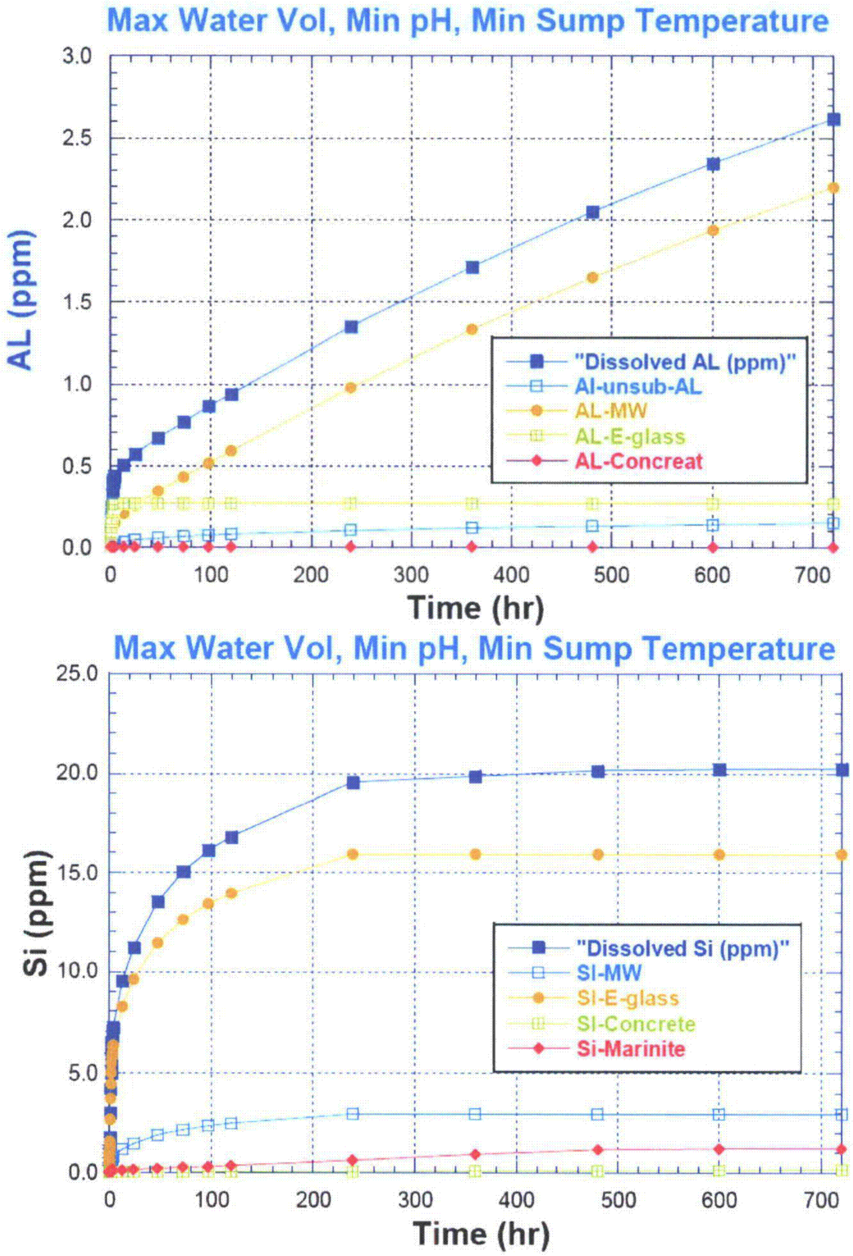
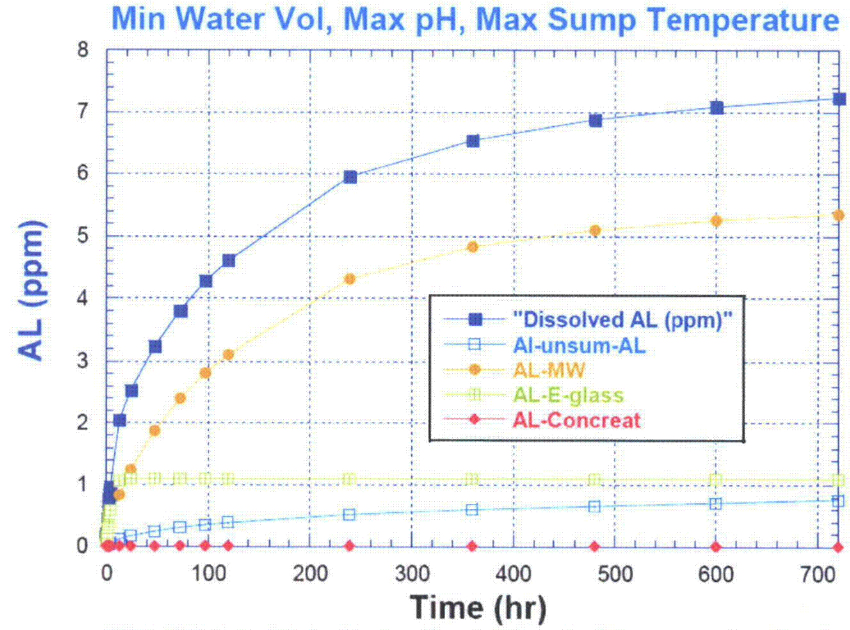


Figure 3: WCAP-16530 CCNPP Aluminum and Silicon Concentration from various sources – Maximum Water Volume, Minimum pH, Minimum Sump Temperature



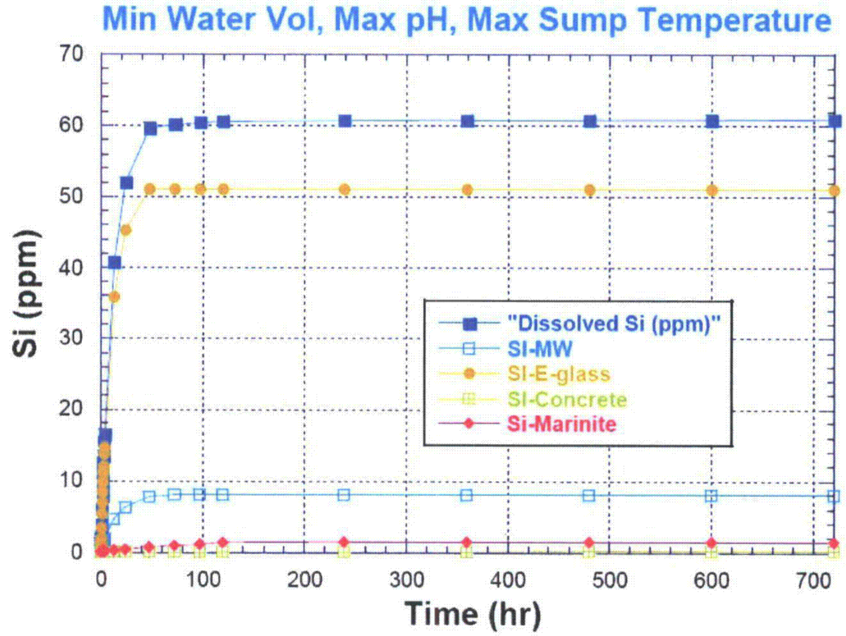


Figure 4: WCAP-16530 CCNPP Aluminum and Silicon Concentration from various sources – Minimum Water Volume, Maximum pH, Maximum Sump Temperature

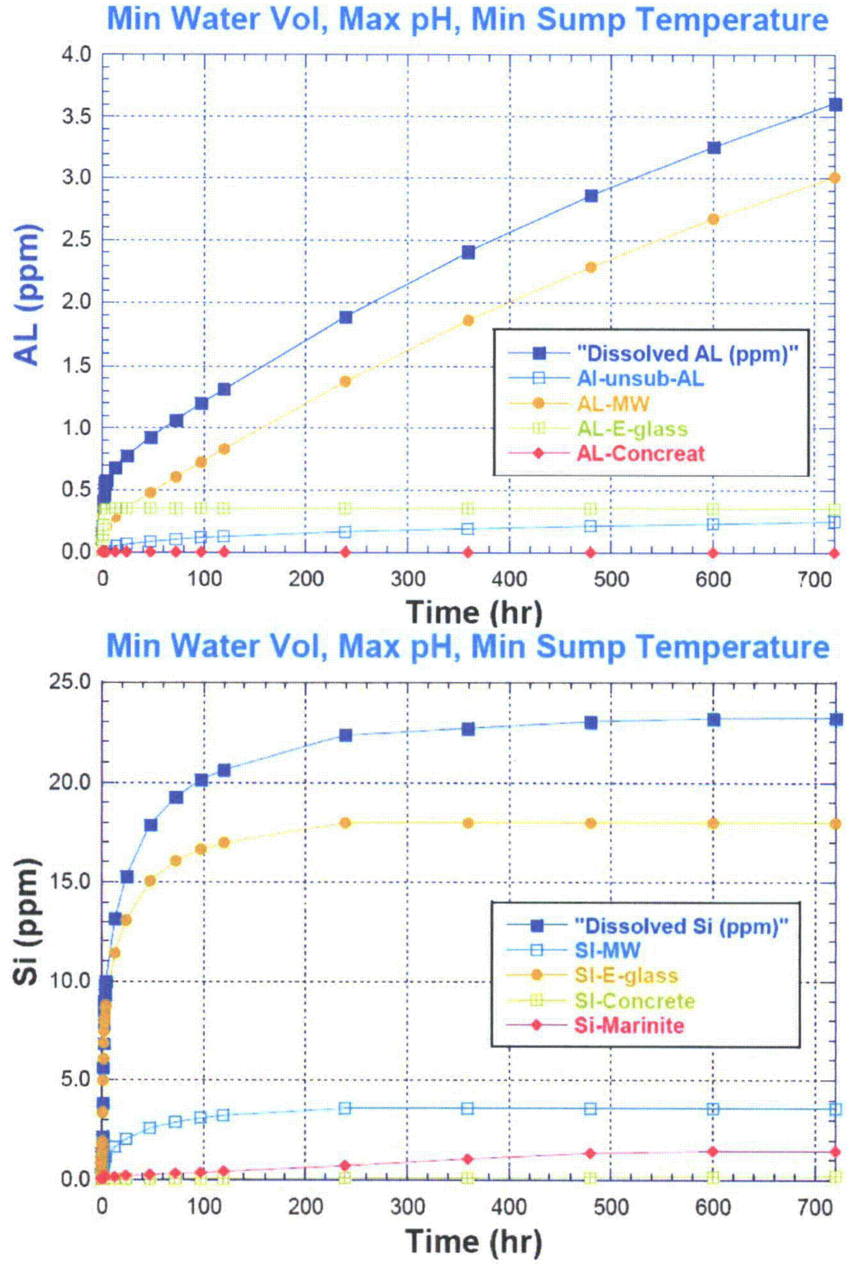


Figure 5: WCAP-16530 CCNPP Aluminum and Silicon Concentration from various sources – Minimum Water Volume, Maximum pH, Minimum Sump Temperature

4.0 CCNPP NAS HEAD LOSS TEST RESULTS

Vertical loop chemical effect testing performed using a NaTB buffered boric acid solution with 10 ppm dissolved aluminum and 60 ppm dissolved silicon indicated that there is no significant increase in head loss due to chemical effect precipitation at temperatures down to 60°F as shown in Figure 6 [Ref. 8.1]. This indicates that aluminum precipitate formation at CCNPP, if it occurs at all, does not detectably increase strainer head loss at temperatures above 60°F, which is consistent with other testing performed with chemistry similar to CCNPP [Ref. 8.15]. During CCNPP vertical loop chemical effect testing, in addition to the lack of measured head loss impact, there was no visual indication of aluminum oxyhydroxide formation or precipitation.

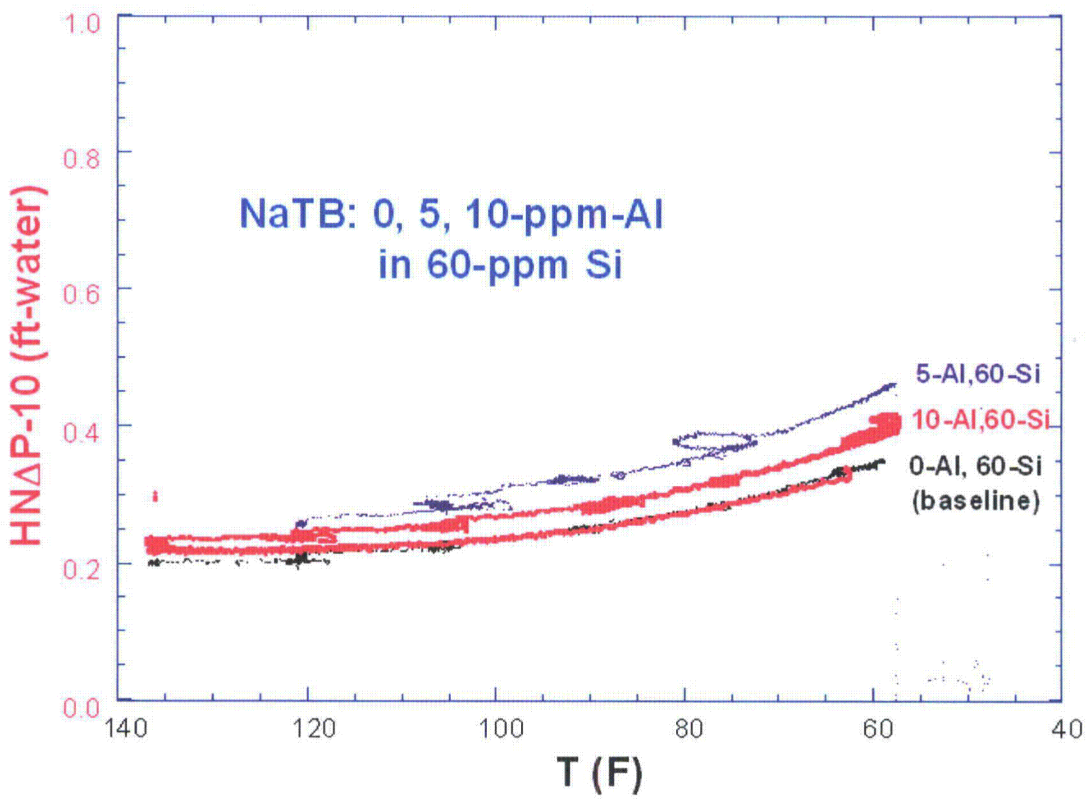


Figure 6: Raw differential pressure data [NaTB buffered Borated water solution, 60-ppm Si, 0, 5, & 10 ppm Al]

From analysis of the data shown above for the measured head loss as a function of test temperature, it can be determined that the temperature-dependent head loss variation can be attributed to the test loop fluid viscosity increase with decreasing temperature rather than chemical effects. Variations between results for the different aluminum concentration levels manifest uniformly at all temperature levels and are merely indicative of minor variations in the test debris bed between tests.

The head loss test from NUREG/CR-6913 with chemistry most similar to CCNPP is test ICET-5-1-B2. The results of this test are shown in Figure 7 below.

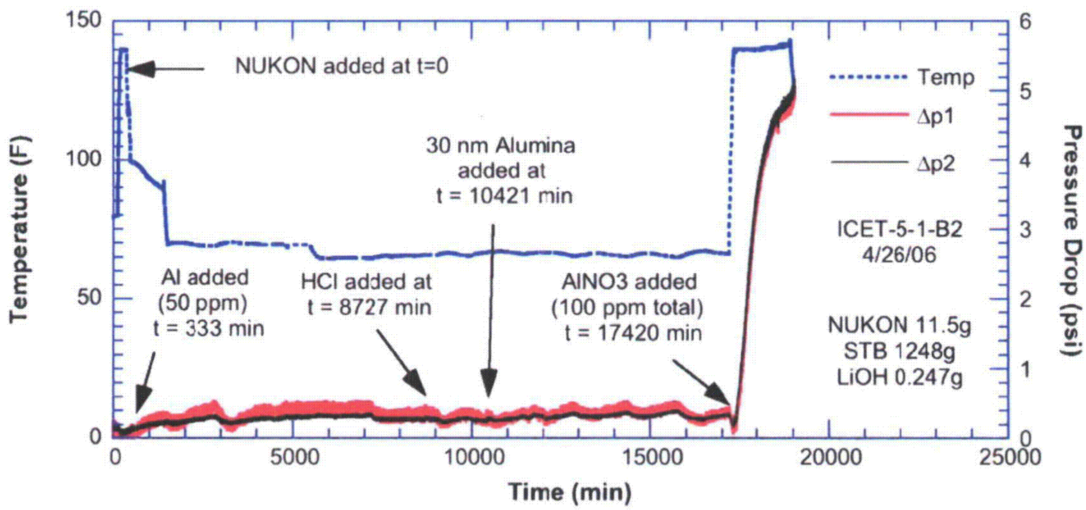


Figure 7: Pressure and velocity history in test ICET-5-1-B2_042606

(Figure 66 from NUREG/CR-6913 [Ref. 8.15])

As can be seen, the head loss did not increase significantly until the aluminum concentration reached 100 ppm. Recall that the maximum aluminum concentration at CCNPP is less than 10 ppm.

Alion also performed head loss test using NaTB buffered boric acid solution with 10 ppm dissolved aluminum with and without 60 ppm dissolved silicon. This testing involved the use of solid aluminum nitrate nonahydrate for the aluminum ion source and a laboratory-grade sodium silicate solution for the silicon which allows for in-situ formation of AlOOH when silicon is absent and NAS with silicon present in sufficient concentration.

Results of head loss tests with 10 ppm aluminum with and without 60 ppm dissolved silicon are shown below.

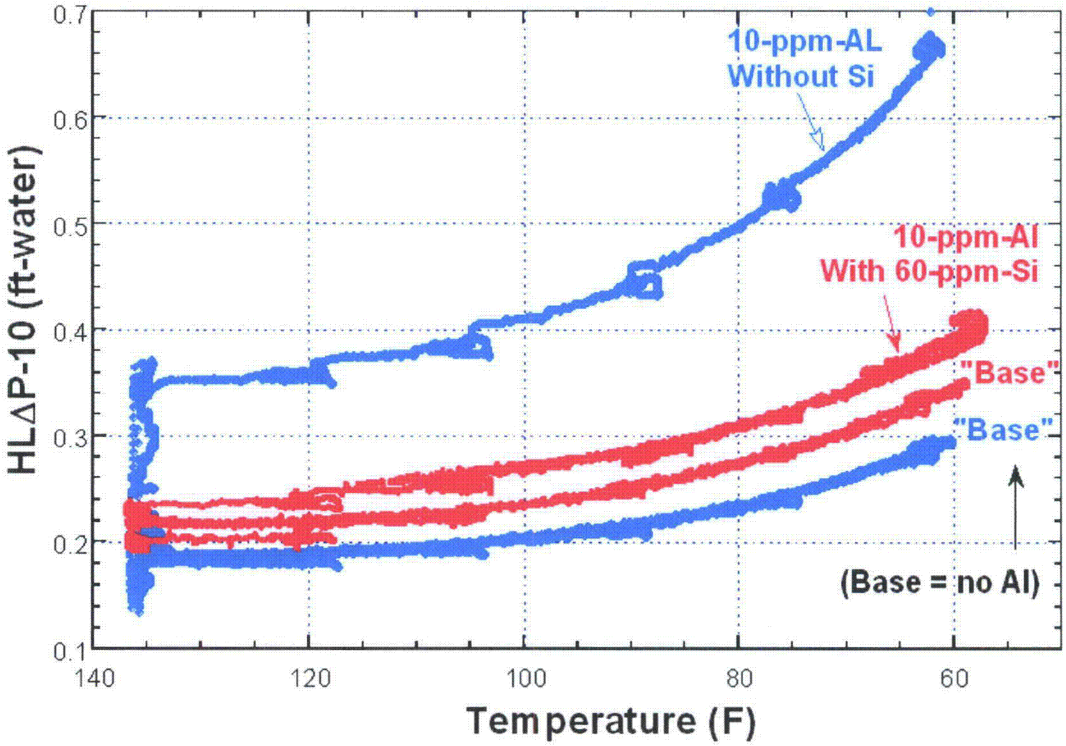


Figure 8: Vertical Loop tests – 10 ppm Aluminum with and without 60 ppm Silicon

These test results demonstrate the influence of silicon in reducing head loss. The reason for this head loss reduction is twofold:

1. At CCNPP there is an excess of silicon (i.e., greater than a 3.12:1 ratio) in all accident scenarios, which allows for the precipitation of NAS in lieu of AlOOH due to the reduced solubility and thermodynamic stability of NAS. Thermodynamic theory predicts the precipitation of NAS before that of AlOOH, which would prevent dissolved aluminum from forming AlOOH.

2. Alion conducted bench-top tests to determine the volumes of precipitated NAS and AlOOH based on the same mass of added aluminum. The tests were not prototypic but instead comparative in nature, and used much higher concentrations of aluminum than are predicted for

the CCNPP post-LOCA sump to encourage precipitation and maximize the measurable effects of the absence and presence of silicon. The results of the bench-top testing indicate that for a given mass of dissolved aluminum, the volume of AlOOH emulsion is approximately 10 times that of sodium aluminum silicate precipitate.

Applying these results to a pore-clogging model of head loss due to chemical effects, dissolved aluminum in the presence of excess silicon would have approximately $1/10^{th}$ the effect on head loss as dissolved aluminum without silicon. The exact relative magnitude of the effect on head loss is unclear due to the unknown particle size of the precipitate and the AlOOH-water emulsification behavior, but the order-of-magnitude-difference in precipitate volumes alone suggests that AlOOH will have a significantly greater effect on head loss than NAS. Electrochemical interactions with the debris bed and differences in particle size may increase the differentiation, but this is beyond the scope of the bench-top testing.

5.0 ANL SOLUBILITY OF AL PROVIDED BY NRC

Argonne National Laboratory developed bounding estimates of aluminum solubility in alkaline environments consisting of NaOH buffered solutions w/o any dissolved silicon [Ref. 8.16]. Such an environment would favor aluminum precipitation in the form of AlOOH when precipitation does occur. These data are conservative in that they predict precipitate formation at conditions (pH and temperature) for which the previously discussed data clearly shows no head loss impact. While the data are not directly applicable to CCNPP due to the lack of silicon in the solution, they will be considered nonetheless as a means of developing a technical position on chemical effects at CCNPP.

The key results from the ANL study are presented in Figure 9. Solubility at a pH of 7.0 and 7.5 are presented for two sets of aluminum dissolution data.

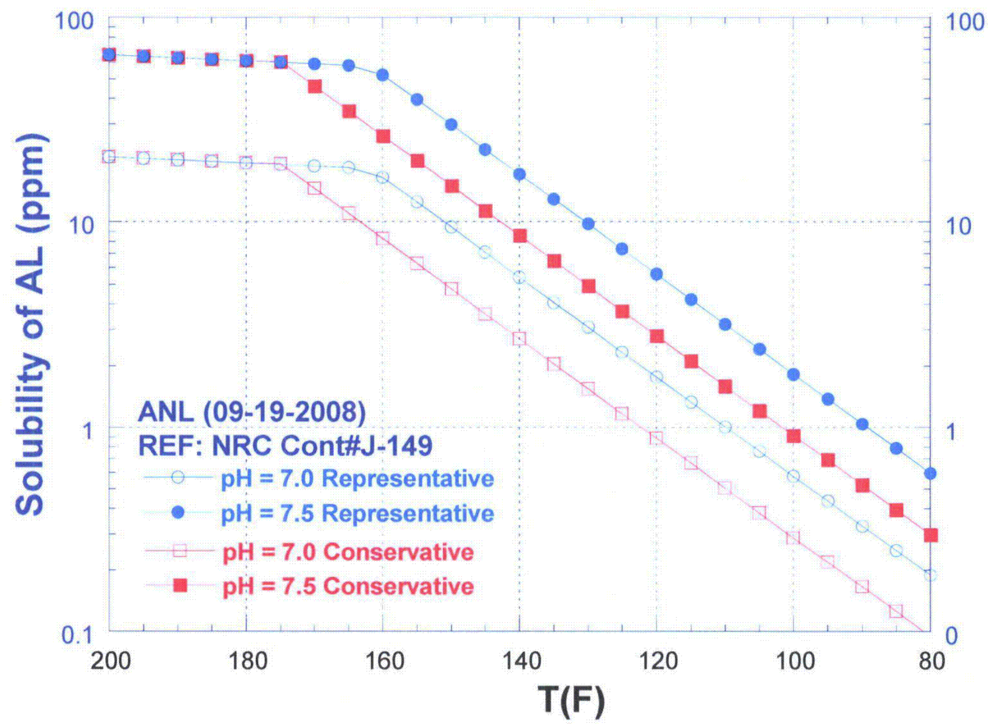


Figure 9: Concentration of Aluminum as a function of temperature and pH Data derived from empirical analysis of the ANL AlOOH data.

Relative to the two sets of data presented, two observations should be noted:

1. The "conservative" solubility curves above (lines with squares) represent the lower bound on available data including two specific ANL corrosion tests using 6061 and 1100 aluminum plates. The "representative" solubility curves (lines with circles) represent the lower bound on available data excluding these two specific ANL corrosion tests.

2. As stated in the ANL Technical Letter Report on Evaluation of Head Loss by Products of Aluminum Alloy Corrosion [Ref. 8.17]; "The ANL corrosion vertical head loss loop tests with 6061 and 1100 plates seem to suggest somewhat lower solubility than the chemical Al tests.

As previously stated, CCNPP has very little structural aluminum in containment. The majority of dissolved aluminum in the CCNPP post-LOCA containment sump is dissolved from fibrous insulation (90%) and not from structural aluminum (10%). Because the "conservative" ANL solubility curve it is based primarily on two tests using only structural aluminum plates and these results appear as outliers compared to the remaining data which used other sources of aluminum more representative of those in the CCNPP sump fluid, it is more appropriate to compare the "representative" ANL solubility curves to the CCNPP sump chemistry conditions.

Additionally, the testing performed at Argonne that formed the basis for this aluminum solubility data was based on visual observations of precipitation at aluminum concentrations between 40 and 98 ppm [Ref. 8.18] and head loss increases at aluminum concentrations greater than 100 ppm [Ref. 8.17]. The extrapolation of the ANL aluminum solubility correlations to the conditions of the post-LOCA sump at CCNPP, which contains less than 10 ppm dissolved aluminum, involves the application of an empirical correlation to conditions that are not bounded by the body of empirical evidence used to derive the correlation.

Measurements reported in Appendix B of reference 8.16 contradict the ANL correlation with regard to aluminum solubility in the range of aluminum concentrations that are extrapolated beyond the source data. ANL post-test solution sample supernate at a pH of 7.0 and at room temperature contained 2.2-4.5 ppm aluminum, per ICP analysis, which is a significantly higher dissolved aluminum content than predicted by the ANL correlation for those conditions. The ANL aluminum solubility correlation predicts aluminum solubility at pH 7 and 76° to be 0.15 ppm using the representative data and 0.08 ppm using the conservative data. This supports the conclusion that the ANL solubility correlation under predicts aluminum solubility at aluminum concentrations below those found in the source data.

5.1 ANL Solubility Data Applied to Calvert Cliffs Precipitate Results

Figure 10 and Figure 11 below show the generation of NAS precipitate versus time as predicted by the WCAP-16530 methodology for the various conditions of maximum sump volume/minimum pH, minimum sump volume/maximum pH, and maximum and minimum sump temperature discussed in Section 3.2. Also shown are the aluminum and silicon dissolution curves from this same WCAP analysis as well as the ANL aluminum solubility curves from the ANL study. The representative solubility curves from the ANL study are shown in all cases presented below.

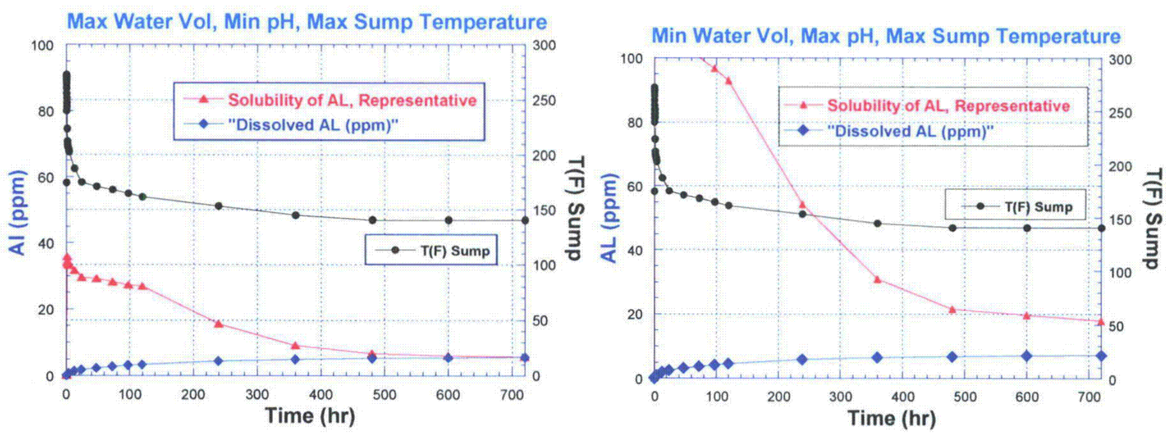


Figure 10: Solubility of Al with the chemical precipitate, Maximum Sump Temperature Cases

This shows that, based on the ANL solubility data, the WCAP predicted aluminum concentration remains below the representative ANL solubility limit at maximum sump temperature conditions, indicating that there would be no precipitation down to the minimum temperature of 140.8°F.

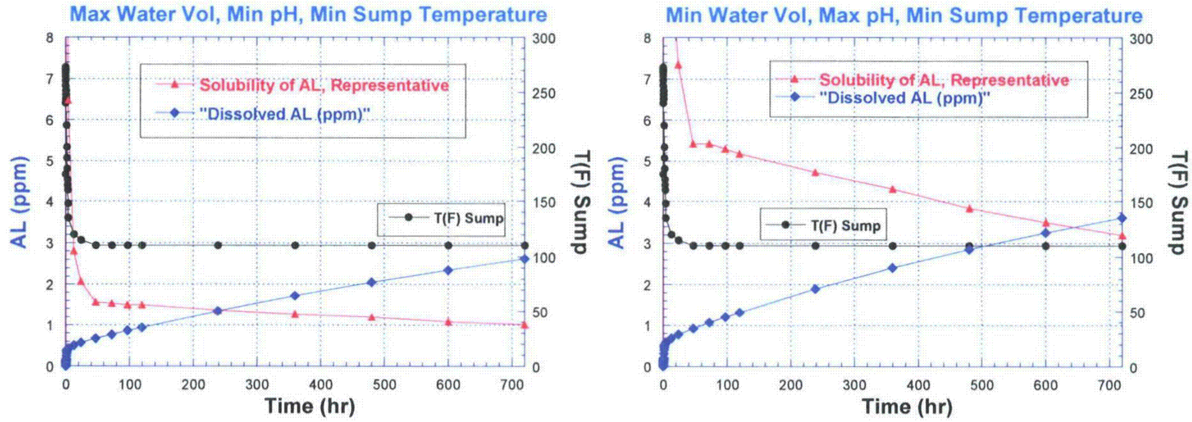


Figure 11: Solubility of Al with the chemical precipitate, Minimum Sump Temperature Cases

The minimum sump temperature results indicate that the aluminum concentration predicted by the WCAP methodology exceeds the ANL solubility limit for AlOOH for both the minimum and maximum pH cases. For the minimum pH case, the aluminum solubility and concentration lines intersect at approximately 1.5 ppm at ~250 hours, corresponding to a temperature of 110°F. For the maximum pH case, the aluminum solubility and concentration lines intersect at approximately 3.4 ppm at ~645 hours, also corresponding to a temperature of 110°F.

6.0 CONCLUSIONS

1) CCNPP used a conservative method for determining the aluminum corrosion rate and the associated total dissolved aluminum chemical effects precipitate source term, consistent with WCAP-16530.

2) CCNPP has sufficient fiberglass insulation debris in the sump to maintain a silicon to aluminum mass ratio greater than 3.12. This favors sodium aluminum silicate (NAS) precipitate formation over aluminum oxyhydroxide (AlOOH).

3) Vertical loop head loss testing done with CCNPP specific sump chemistry and the dissolved quantities of aluminum and silicon predicted by the WCAP-16530 methodology produced no significant head loss for the entire range of temperatures down to 60°F.

4) The testing performed at Argonne that formed the basis for this ANL aluminum solubility data was based on visual observations of precipitation at aluminum concentrations between 40 and 98 ppm and head loss increases at aluminum concentrations greater than 100 ppm. The extrapolation of the ANL aluminum solubility correlations to the conditions of the post-LOCA sump at CCNPP, which contains less than 10 ppm dissolved aluminum, involves the application of an empirical correlation to conditions that are not bounded by the body of empirical evidence used to derive the correlation and includes significant uncertainty.

5) The testing performed at Argonne that formed the basis for the ANL aluminum solubility data includes data that contradict the ANL correlation with regard to aluminum solubility in the range of aluminum concentrations that are extrapolated beyond the source data. This supports the conclusion that the ANL solubility correlation under predicts aluminum solubility at aluminum concentrations below those found in the source data.

6) A conservative approach for addressing chemical effects on sump performance at CCNPP is to apply the head loss for the entire WCAP-16530 estimated quantity of NAS after the sump fluid cools to 110°F.

7.0 CONSERVATISMS

Taking the position on chemical effects discussed above, the following conservative considerations remain in the CCNPP sump performance evaluation of chemical effects:

1) CCNPP-specific vertical loop testing showed no significant head loss due to potential aluminum precipitates when tested with aluminum concentrations exceeding that calculated for CCNPP and for temperatures lower than possible at CCNPP. However, CCNPP is applying 100% of the head loss impact from precipitates generated in accordance with WCAP-16530 once a conservative threshold temperature for chemical effects is reached.

2) The ANL Aluminum Solubility data used to determine temperature threshold for precipitation are based on aluminum oxyhydroxide (AlOOH) formation in a low/no silicon environment. The CCNPP post-LOCA sump is predicted to have significantly more silicon than aluminum which would preferentially form sodium aluminum silicate (NAS) and not AlOOH.

3) The testing performed at Argonne that formed the basis for this aluminum solubility data was based on visual observations of precipitation at aluminum concentrations between 40 and 98 ppm and head loss increases at aluminum concentrations greater than 100 ppm. The extrapolation of ANL aluminum solubility correlations to the conditions of the post-LOCA sump at CCNPP, which contains less than 10 ppm dissolved aluminum, involves the application of an empirical correlation to conditions that are not bounded by the body of ANL empirical evidence used to derive the correlation and is very uncertain.

4) The testing performed at Argonne that formed the basis for the ANL aluminum solubility data includes data that contradict the ANL correlation with regard to aluminum solubility in the range of aluminum concentrations that are extrapolated beyond the source data. This supports the conclusion that the ANL solubility correlation under predicts aluminum solubility at aluminum concentrations below those found in the source data.

5) CCNPP used a conservative method for determining the aluminum corrosion rate and the associated total dissolved aluminum precipitate debris source term, consistent with WCAP-

16530. The CCNPP post-LOCA sump aluminum concentration determined with this conservative methodology is less than 10 ppm.

6) An Alion aluminum corrosion test using NaTB buffered solution at a pH of 8.3 with other materials including zinc, concrete, and fiberglass insulation resulted in an aluminum concentration less than 1/10th of the concentration predicted by WCAP-16530. The maximum pH of the CCNPP sump post-LOCA is 7.6 which would result in an even lower aluminum corrosion rate and less dissolved aluminum in the sump fluid. This further demonstrates the conservatism of the use of the WCAP aluminum quantities.

8.0 REFERENCES

8.1. Design Calculation CA07051, Rev. 0000, Chemical Effect Head Loss Test Report

8.2. Design Calculation CA07055, Rev. 0001 (ALION-REP-CCNPP-7311-001, CCNPP Chemical Effects Vertical Loop Head Loss Test Report, Revision 2).

8.3. Westinghouse report WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191", February 2006, Revision 0.

8.4. Westinghouse letter WOG-06-102, "Distribution of Errata to WCAP-16530-NP, 'Method for Evaluating Post-Accident Chemical Effects in Containment Sump Fluids' (PA-SEE-0275)", March 17, 2006.

8.5. Westinghouse letter OG-06-255, "Letter Releasing Revised Chemical Model Spreadsheet from WCAP 16530-NP," August 7, 2006.

8.6. Westinghouse letter OG-06-273, "PWR Owners Group Method Description of Error Discovered August 16, 2006 in Revised Chemical Model Spreadsheet (PA-SEE-0275)," August 28, 2006.

8.7. Westinghouse letter OG-06-378, "PWR Owners Group Letter Issuing Revised Chemical Model Spreadsheet (PA-SEE-0275)," November 15, 2006.

8.8. Westinghouse letter WOG-06-107, "PWR Owners Group Letter to NRC Regarding Error Corrections to WCAP-16530-NP (PA-SEE-0275)," March 21, 2006.

8.9. Final Safety Evaluation by the Office Of Nuclear Reactor Regulation, Topical Report WCAP-16530-NP "Evaluation Of Post-Accident Chemical Effects In Containment Sump Fluids To Support GSI-191", Pressurized Water Reactor Owners Group. Project No. 694.

8.10. Design Calculation CA06963, Revision 0001, Mass of Sodium Tetraborate Decahydrate Buffer Required for Post LOCA Containment Building Sump pH Control,

8.11. Design Calculation CA07047, Rev. 0000, Chemical Product Formation with NaTB Buffer.

8.12. ALION-REP-LAB-2352-219, Test Report: Aluminum, Zinc, Insulation, and Concrete Corrosion and Dissolution in TSP and NaTB, Revision 1.

8.13. Design Calculation CA06485, Revision 0003, Determination of Insulation Debris Loads on Emergency Sump Strainer.

8.14. Letter from Mr. D. R. Bauder (CCNPP) to Document Control Desk (NRC), dated August 27, 2008, License Amendment Request: Replacement of the Trisodium Phosphate Buffer with a Sodium Tetraborate Buffer.

8.15. NUREG/CR-6913, Chemical Effects Head-Loss Research in Support of Generic Safety Issue 191, Section 3.5.1 and Figure 66, December, 2006.

8.16. Argonne National Laboratory Report, Aluminum Solubility in Boron Containing Solutions as a Function of pH and Temperature, NRC Contract # J-4149, September 19, 2008.

8.17. Argonne National Laboratory Technical Letter Report on Evaluation of Head Loss by Products of Aluminum Alloy Corrosion, NRC Contract # JCN-3216, August 11, 2008.

8.18. Argonne National Laboratory Technical Letter Report on Evaluation of Long-term Aluminum Solubility in Borated Water Following a LOCA, NRC Contract # JCN-3216, February 25, 2008.

8.19. Design Calculation CA06774, Revision 0002, Containment Response to LOCA & MSLB for Calvert Cliffs Units 1 & 2.

Appendix I

Aluminum Dissolution Curve WCAP Data

WCAP Temperature and pH Conditions for the Bench-Top Test

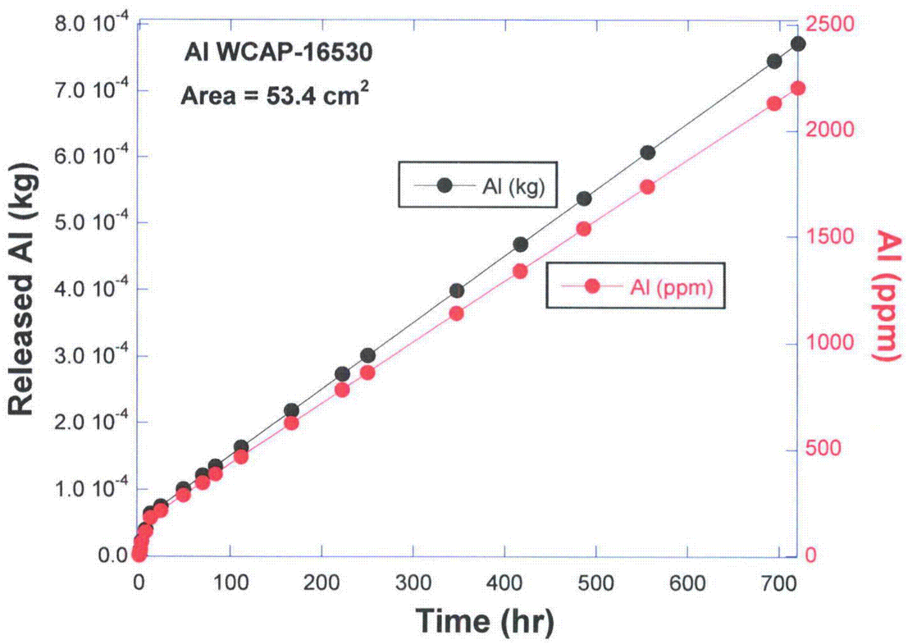
Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Sump Mixed 1=Yes	Steam or Spray pH	Containment Temp. (°F)
6	0	0	0	4.5	200.0	0		
300	5.0	0	0	5.3	200.0	0		
600	10.0	0	0	6.2	200.0	0		
900	15	0	0	7	200.0	0		
1200	20	0	0	7.8	200.0	0		
1260	21	0	0	8.3	200.0	0		
1800	30	1	0	8.3	200.0	0		
2100	35	1	0	8.3	200.0	0		
2400	40	1	0	8.3	200.0	0		
2700	45	1	0	8.3	200.0	0		
3000	50	1	0	8.3	200.0	0		
3300	55	1	0	8.3	200.0	0		
3600	60	1	0	8.3	200.0	0		
3900	65	1	0	8.3	200.0	0		
4200	70	1	0	8.3	200.0	0		
4540	76	1	0	8.3	200.0	0		
4600	77	1	0	8.3	200.0	0		
10000	167	3	0	8.3	200.0	0		
17500	292	5	0	8.3	200.0	0		
45000	750	13	1	8.3	140.0	0		
85000	1417	24	1	8.3	140.0	0		
175000	2917	49	2	8.3	140.0	0		
250000	4167	69	3	8.3	140.0	0		
300000	5000	83	3	8.3	140.0	0		
400000	6667	111	5	8.3	140.0	0		
600000	10000	167	7	8.3	140.0	0		
800000	13333	222	9	8.3	140.0	0		
900000	15000	250	10	8.3	140.0	0		
1250000	20833	347	14	8.3	140.0	0		
1500000	25000	417	17	8.3	140.0	0		
1750000	29167	486	20	8.3	140.0	0		
2000000	33333	556	23	8.3	140.0	0		
2500000	41667	694	29	8.3	140.0	0		
2592000	43200	720	30	8.3	140.0	0		

WCAP-16530 Material Input for Bench-Top Test

Class	Material	Amount	Density (lb/ft3)	Mass(kg)	Class total (kg)
Coolant	Sump Pool Volume (ft3)	0.0126583	60.957	0.4	0.3500
Metallic Aluminum	Aluminum Submerged (sq ft)	0.05750		0.0	45.4
	Aluminum Submerged (lbm)	100.00		45.4	
	Aluminum Not-Submerged (sq ft)	0		0.0	
	Aluminum Not-Submerged (lbm)	0		0.0	
Calcium Silicate	Marinite Insulation(ft3)	0	14.5	0.0	0.0
	Asbestos Insulation (ft3)	0	14.5	0.0	
	Kaylo Insulation (ft3)	0	14.5	0.0	
	Unibestos Insulation (ft3)	0	14.5	0.0	
E-glass	Fiberglass Insulation (ft3)	0	4	0.0	0.0
	NUKON (ft3)	0	4	0.0	
	Temp-Mat (ft3)	0	4	0.0	
	Thermal Wrap (ft3)	0	16	0.0	
Silica Powder	Microtherm (ft3)	0	4	0.0	0.0
	Min-K (ft3)	0	4	0.0	
Mineral Wool	Min-Wool (ft3)	0	8	0.0	0.0
	Rock Wool (ft3)	0	10	0.0	
Aluminum Silicate	Cerablanket (ft^3)	0	12	0.0	0.0
	FiberFrax Durablanket (ft3)	0	12	0.0	
	Kaowool (ft3)	0	12	0.0	
	Mat-Ceramic (ft3)	0	12	0.0	
	Mineral Fiber (ft3)	0	21	0.0	
	PAROC Mineral Wool (ft3)	0	21	0.0	
Concrete	Concrete (ft2)	0		0	0
Interam	Interam (ft3)	0	54	0.0	0.0

WCAP-16530 Aluminum Release Results

Interval Duration (min)	Start of Interval (hrs)	End of Interval (hrs)	Average Interval pH	Average Temp (F)	Ca Release (kg)	Si Release (kg)	Al Release (kg)	$NaAlSi_3O_8$ Precipitate (kg)	AlOOH Precipitate (kg)	$Ca_3(PO_4)_2$ Precipitate (kg)	Al Release (ppm)
4.9	0.00	0.1	4.9	200	0.0000	0.0000	0.00000022	0.000	0.000	0.000	0.63
5.0	0.08	0.2	5.75	200	0.00	0.00	0.00000046	0.0	0.0	0.00	1.32
5.0	0.17	0.3	6.6	200	0.00	0.00	0.00000076	0.0	0.0	0.00	2.18
5.0	0.25	0.3	7.4	200	0.00	0.00	0.00000118	0.0	0.0	0.00	3.38
1.0	0.33	0.4	8.05	200	0.00	0.00	0.00000130	0.0	0.0	0.00	3.73
9.0	0.35	0.5	8.3	200	0.00	0.00	0.00000260	0.0	0.0	0.00	7.42
5.0	0.50	0.6	8.3	200	0.00	0.00	0.00000332	0.0	0.0	0.00	9.48
5.0	0.58	0.7	8.3	200	0.00	0.00	0.00000404	0.0	0.0	0.00	11.53
5.0	0.67	0.8	8.3	200	0.00	0.00	0.00000476	0.0	0.0	0.00	13.59
5.0	0.75	0.8	8.3	200	0.00	0.00	0.00000547	0.0	0.0	0.00	15.64
5.0	0.83	0.9	8.3	200	0.00	0.00	0.00000619	0.0	0.0	0.00	17.70
5.0	0.92	1.0	8.3	200	0.00	0.00	0.00000691	0.0	0.0	0.00	19.75
5.0	1.00	1.1	8.3	200	0.00	0.00	0.00000763	0.0	0.0	0.00	21.80
5.0	1.08	1.2	8.3	200	0.00	0.00	0.00000835	0.0	0.0	0.00	23.86
5.7	1.17	1.3	8.3	200	0.00	0.00	0.00000917	0.0	0.0	0.00	26.19
1.0	1.26	1.3	8.3	200	0.00	0.00	0.00000931	0.0	0.0	0.00	26.60
90.0	1.28	2.8	8.3	200	0.00	0.00	0.00002225	0.0	0.0	0.00	63.57
125.0	2.78	4.9	8.3	200	0.00	0.00	0.00004022	0.0	0.0	0.00	114.92
458.3	4.86	12.5	8.3	170	0.00	0.00	0.00006428	0.0	0.0	0.00	183.65
666.7	12.50	23.6	8.3	140	0.00	0.00	0.00007539	0.0	0.0	0.00	215.39
1500.0	23.61	48.6	8.3	140	0.00	0.00	0.00010039	0.0	0.0	0.00	286.82
1250.0	48.61	69.4	8.3	140	0.00	0.00	0.00012122	0.0	0.0	0.00	346.34
833.3	69.44	83.3	8.3	140	0.00	0.00	0.00013511	0.0	0.0	0.00	386.02
1666.7	83.33	111.1	8.3	140	0.00	0.00	0.00016289	0.0	0.0	0.00	465.39
3333.3	111.11	166.7	8.3	140	0.00	0.00	0.00021844	0.0	0.0	0.00	624.12
3333.3	166.67	222.2	8.3	140	0.00	0.00	0.00027399	0.0	0.0	0.00	782.84
1666.7	222.22	250.0	8.3	140	0.00	0.00	0.00030177	0.0	0.0	0.00	862.21
5833.3	250.00	347.2	8.3	140	0.00	0.00	0.00039899	0.0	0.0	0.00	1139.98
4166.7	347.22	416.7	8.3	140	0.00	0.00	0.00046843	0.0	0.0	0.00	1338.39
4166.7	416.67	486.1	8.3	140	0.00	0.00	0.00053788	0.0	0.0	0.00	1536.79
4166.7	486.11	555.6	8.3	140	0.00	0.00	0.00060732	0.0	0.0	0.00	1735.20
8333.3	555.56	694.4	8.3	140	0.00	0.00	0.00074621	0.0	0.0	0.00	2132.02
1533.3	694.44	720.0	8.3	140	0.00	0.00	0.00077176	0.0	0.0	0.00	2205.03



WCAP-16530 Aluminum Release Results

Appendix 2

Containment Temperature Profile Estimate

The containment temperature profiles available in CCNPP design calculations are developed to support containment response analysis. These temperature profiles are developed using conservative assumptions that tend to maximize temperatures. The solubility of aluminum precipitates is a function of temperature and is maximized at high temperature and minimized at lower temperature. Therefore, the use of temperature profiles using conservative assumptions that tend to maximize temperatures is not necessarily conservative when considering the head loss consideration of aluminum precipitates.

The containment response temperature profile was obtained from calculation CA06774, *Containment Response to LOCA & MSLB for Calvert Cliffs Units 1 & 2*, Revision 2. These temperature profiles terminate before 30 days. The temperatures were conservatively assumed to remain constant to 30 days for use in the WCAP spreadsheets.

A low containment temperature profile was developed based on an assumed more rapid cool down from peak accident conditions is the containment response analysis. A table of the containment response analysis and the assumed low containment temperature profile is provided on the following page.

Containment Atmosphere and Sump Temperature Profiles

Time (sec)	Orig. Sump Temp. (°F)	Orig Containment Temp. (°F)	Low Sump Temp. (°F)	Low Containment Temp. (°F)
6	174.8	248.0	174.8	248.0
30	240.1	262.4	240.1	262.4
60	267.6	271.3	267.6	271.3
120	270.6	269.1	270.6	269.1
180	272.3	271.5	272.3	271.5
200	272.6	271.3	272.6	271.3
400	271.7	264.0	271.7	264.0
600	268.4	254.2	268.4	254.2
800	264.7	245.1	264.7	245.1
1000	260.7	236.6	260.7	236.6
1204	256.2	228.1	256.2	228.1
1405	251.8	220.2	251.8	220.2
1607	247.7	212.5	247.7	212.5
1811	243.9	205.4	243.9	205.4
3216	223.9	188.9	220.0	180.0
4620	212.2	186.3	200.0	175.0
6023	209.6	184.9	190.0	170.0
7427	208.0	189.0	180.0	165.0
8832	206.7	189.5	170.0	160.0
10035	205.8	188.7	165.0	155.0
11036	205.0	188.0	160.0	150.0
13036	203.6	187.1	148.0	145.0
14037	202.9	186.7	135.0	140.0
46049	187.6	168.5	120.0	135.0
86077	175.2	156.3	115.0	130.0
170089	171.4	148.5	110.0	120.0
260097	168.5	143.8	110.0	115.0
350108	164.9	138.9	110.0	110.0
430123	161.6	134.1	110.0	105.0
860168	153.6	123.1	110.0	98.0
1295340	145.2	113.4	110.0	92.0
1728000	140.8	110.0	110.0	90.0
2160000	140.8	110.0	110.0	90.0
2592000	140.8	110.0	110.0	90.0

Appendix 3

WCAP-16530 Spreadsheets

The spreadsheet tables presented in this appendix are the data input and certain results tables from the WCAP-16530 spreadsheets for the four bounding cases evaluated.

Maximum ph, Maximum Temperature Data

[Source: Min Water Vol, Max pH, Max Sump Temperature.xlsx]

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Sump Mixed 1=Yes	Steam or Spray pH	Containment Temp. (°F)	Notes
6	0	0	0	4.5	174.8	0	4.5	248.0	RCS blowdown
30	0.5	0	0	4.5	240.1	0	4.5	262.4	
60	1.0	0	0	4.5	267.6	0	4.5	271.3	
120	2	0	0	4.5	270.6	0	4.5	269.1	
180	3	0	0	4.5	272.3	0	4.5	271.5	
200	3	0	0	4.5	272.6	0	4.5	271.3	
400	7	0	0	4.5	271.7	0	4.5	264.0	
600	10	0	0	4.5	268.4	0	4.5	254.2	
800	13	0	0	4.5	264.7	0	4.5	245.1	
1000	17	0	0	4.5	260.7	0	4.5	236.6	
1204	20	0	0	4.5	256.2	0	4.5	228.1	
1405	23	0	0	4.5	251.8	0	4.5	220.2	
1607	27	0	0	4.5	247.7	0	4.5	212.5	
1811	30	1	0	4.5	243.9	0	4.5	205.4	Start of Recirculation Phase
3216	54	1	0	7.75	223.9	0	7.75	188.9	
4620	77	1	0	7.75	212.2	0	7.75	186.3	
6023	100	2	0	7.75	209.6	0	7.75	184.9	
7427	124	2	0	7.75	208.0	0	7.75	189.0	
8832	147	2	0	7.75	206.7	0	7.75	189.5	
10035	167	3	0	7.75	205.8	0	7.75	188.7	
11036	184	3	0	7.75	205.0	0	7.75	188.0	
13036	217	4	0	7.75	203.6	0	7.75	187.1	
14037	234	4	0	7.75	202.9	0	7.75	186.7	
46049	767	13	1	7.75	187.6	0	7.75	168.5	
86077	1435	24	1	7.74	175.2	0	7.74	156.3	
170089	2835	47	2	7.73	171.4	0	7.73	148.5	
260097	4335	72	3	7.73	168.5	0	7.73	143.8	
350108	5835	97	4	7.72	164.9	0	7.72	138.9	
430123	7169	119	5	7.71	161.6	0	7.71	134.1	
860168	14336	239	10	7.67	153.6	0	7.67	123.1	
1295340	21589	360	15	7.63	145.2	0	7.63	113.4	
1728000	28800	480	20	7.58	140.8	0	7.58	110.0	
2160000	36000	600	25	7.54	140.8	0	7.54	110.0	
2592000	43200	720	30	7.50	140.8	0	7.5	110.0	

Maximum ph, Maximum Temperature Data Continued

[Source: Min Water Vol, Max pH, Max Sump Temperature.xlsx]

Class	Material	Amount	Notes
Coolant	Sump Pool Volume (ft3)	62879	Should run sensitivities with both maximum and minimum
Metallic Aluminum	Aluminum Submerged (sq ft)	0	
	Aluminum Submerged (lbm)	0	
	Aluminum Not-Submerged (sq ft)	275	
	Aluminum Not-Submerged (lbm)	1000000	
Calcium Silicate	Marinite Insulation(ft3)	0.5	Other class members include Marinite and MUDD
	Asbestos Insulation (ft3)	0	
	Kaylo Insulation (ft3)	0	
	Unibestos Insulation (ft3)	0	
E-glass	Fiberglass Insulation (ft3)	225	
	NUKON (ft3)	400	
	Temp-Mat (ft3)	35	
	Thermal Wrap (ft3)	500	
Silica Powder	Microtherm (ft3)	0	
	Min-K (ft3)	0	
Mineral Wool	Min-Wool (ft3)	127.57	Removed SDC Line Mineral Wool (42.43 ft^3)
	Rock Wool (ft3)	0	
Aluminum Silicate	Cerablanket (ft3)	0	
	FiberFrax Durablanket (ft3)	0	
	Kaowool (ft3)	0	
	Mat-Ceramic (ft3)	0	
	Mineral Fiber (ft3)	0	
	PAROC Mineral Wool (ft3)	0	
Concrete	Concrete (ft2)	66300	
Trisodium Phosphate (TSP)	Trisodium Phosphate Hydrate (lbm)	0	Flag=0 if no TSP, ≠0 if use TSP as buffering agent
Interam	Interam (ft3)	0	

Maximum ph, Maximum Temperature Data Continued

[Source: Min Water Vol, Max pH, Max Sump Temperature.xlsx]

Class	Material	Amount	Density (lb/ft3)	Mass(kg)	Class total (kg)
Coolant	Sump Pool Volume (ft3)	62879	60.2	1717008.0	1717008.0
Metallic Aluminum	Aluminum Submerged (sq ft)	0.00		0.0	453597.0
	Aluminum Submerged (lbm)	0.00		0.0	
	Aluminum Not-Submerged (sq ft)	275		0.0	
	Aluminum Not-Submerged (lbm)	1000000		453597.0	
Calcium Silicate	Marinite Insulation(ft3)	0.5	46	10.4	10.4
	Asbestos Insulation (ft3)	0	14.5	0.0	
	Kaylo Insulation (ft3)	0	14.5	0.0	
	Unibestos Insulation (ft3)	0	14.5	0.0	
E-glass	Fiberglass Insulation (ft3)	225	5.5	561.3	1728.4
	NUKON (ft3)	400	2.4	435.5	
	Temp-Mat (ft3)	35	11.8	187.3	
	Thermal Wrap (ft3)	500	2.4	544.3	
Silica Powder	Microtherm (ft3)	0	4	0.0	0.0
	Min-K (ft3)	0	4	0.0	
Mineral Wool	Min-Wool (ft3)	127.57	8	462.9	462.9
	Rock Wool (ft3)	0	10	0.0	
Aluminum Silicate	Cerablanket (ft^3)	0	12	0.0	0.0
	FiberFrax Durablanket (ft3)	0	12	0.0	
	Kaowool (ft3)	0	12	0.0	
	Mat-Ceramic (ft3)	0	12	0.0	
	Mineral Fiber (ft3)	0	21	0.0	
	PAROC Mineral Wool (ft3)	0	21	0.0	
Concrete	Concrete (ft2)	66300		0.666845	0.6668454
Interam	Interam (ft3)	0	54	0.0	0.0

Maximum ph, Maximum Temperature Results

[Source: Min Water Vol, Max pH, Max Sump Temperature.xlsx]

Interval Duration (min)	Start of Interval (hrs)	End of Interval (hrs)	Average Interval pH	Average Temp (F)	Ca Release (kg)	Si Release (kg)	Al Release (kg)	$NaAlSi_3O_8$ Precipitate (kg)	AlOOH Precipitate (kg)	$Ca_3(PO_4)_2$ Precipitate (kg)	
0.4	0.00	0.0	4.5	207.471	0.0130	0.0156	0.0014	0.014	0.000	0.000	
0.5	0.01	0.0	4.5	253.873	0.04	0.07	0.01	0.1	0.0	0.00	
1.0	0.02	0.0	4.5	269.1365	0.09	0.22	0.02	0.2	0.0	0.00	
1.0	0.03	0.1	4.5	271.4485	0.14	0.37	0.04	0.4	0.0	0.00	
0.3	0.05	0.1	4.5	272.4435	0.16	0.42	0.05	0.5	0.0	0.00	
3.3	0.06	0.1	4.5	272.1795	0.33	0.94	0.11	1.0	0.0	0.00	
3.3	0.11	0.2	4.5	270.0695	0.50	1.43	0.16	1.6	0.0	0.00	
3.3	0.17	0.2	4.5	266.561	0.66	1.89	0.21	2.0	0.0	0.00	
3.3	0.22	0.3	4.5	262.6905	0.82	2.31	0.25	2.4	0.0	0.00	
3.4	0.28	0.3	4.5	258.4355	0.98	2.71	0.28	2.8	0.0	0.00	
3.3	0.33	0.4	4.5	254.024	1.13	3.06	0.31	3.0	0.0	0.00	
3.4	0.39	0.4	4.5	249.7725	1.27	3.39	0.34	3.3	0.0	0.00	
3.4	0.45	0.5	4.5	245.817	1.41	3.69	0.36	3.5	0.0	0.00	
23.4	0.50	0.9	6.125	233.9115	2.40	6.64	0.56	5.5	0.0	0.00	
23.4	0.89	1.3	7.749932215	218.0395	3.39	10.39	0.78	7.6	0.0	0.00	
23.4	1.28	1.7	7.749796651	210.89	4.29	13.50	0.94	9.1	0.0	0.00	
23.4	1.67	2.1	7.749661077	208.8025	5.14	16.39	1.09	10.6	0.0	0.00	
23.4	2.06	2.5	7.74952546	207.3755	5.96	19.14	1.23	12.0	0.0	0.00	
20.1	2.45	2.8	7.749399531	206.262	6.64	21.40	1.34	13.1	0.0	0.00	
16.7	2.79	3.1	7.749293135	205.392	7.18	23.20	1.43	13.9	0.0	0.00	
33.3	3.07	3.6	7.749148231	204.281	8.23	26.66	1.60	15.6	0.0	0.00	
16.7	3.62	3.9	7.749003308	203.2185	8.72	28.31	1.68	16.4	0.0	0.00	
533.5	3.90	12.8	7.747409278	195.2205	23.11	70.12	3.53	34.3	0.0	0.00	
667.1	12.79	23.9	7.743930816	181.3825	27.73	89.40	4.37	42.5	0.0	0.00	
1400.2	23.91	47.2	7.737941528	173.2835	31.89	102.39	5.59	54.3	0.0	0.00	
1500.1	47.25	72.2	7.729538925	169.931	33.23	103.31	6.60	64.2	0.0	0.00	
1500.2	72.25	97.3	7.720846669	166.7205	34.07	103.75	7.41	72.0	0.0	0.00	
1333.6	97.25	119.5	7.712636928	163.28	34.86	104.11	7.97	77.5	0.0	0.00	
7167.4	119.48	238.9	7.688008571	157.605	35.12	104.31	10.29	100.0	0.0	0.00	
7252.9	238.94	359.8	7.646231384	149.3775	35.26	104.38	11.32	110.0	0.0	0.00	
7211.0	359.82	480.0	7.60432793	143.0025	35.40	104.45	11.87	115.4	0.0	0.00	
7200.0	480.00	600.0	7.562577637	140.841	35.53	104.51	12.23	118.9	0.0	0.00	
7200.0	600.00	720.0	7.520859212	140.841	35.66	104.58	12.47	121.2	0.0	0.00	KG
								267.2	0.00	0.00	LBS

Ca	Si	Al	
20.76666022	60.90796706	7.262271266	ppm

	Releases in kg		
Material Class	Ca	Si	Al
Metallic Aluminum Submerged	0.00	0.00	0.00
Metallic Aluminum Not-Submerged	0.00	0.00	1.31
Calcium Silicate	3.60	2.51	0.00
E-Glass	18.54	87.69	1.90
Silica Powder	0.00	0.00	0.00
Mineral Wool	12.64	13.94	9.23
Aluminum silicate	0.00	0.00	0.00
Concrete	0.88	0.44	0.02
Interam	0.00	0.00	0.00

Metallic Aluminum Not-Submerged		0.0%	10.5%
Calcium Silicate		2.4%	0.0%
E-Glass		83.8%	15.3%
Silica Powder		0.0%	0.0%
Mineral Wool		13.3%	74.0%
Aluminum silicate		0.0%	0.0%
Concrete		0.4%	0.2%

Maximum ph, Minimum Temperature Data

[Source: Min Water Vol, Max pH, Min Sump Temperature.xlsx]

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Sump Mixed 1=Yes	Steam or Spray pH	Containment Temp. (°F)	Notes
6	0	0	0	4.5	174.8	0	4.5	248.0	RCS blowdown
30	0.5	0	0	4.5	240.1	0	4.5	262.4	
60	1.0	0	0	4.5	267.6	0	4.5	271.3	
120	2	0	0	4.5	270.6	0	4.5	269.1	
180	3	0	0	4.5	272.3	0	4.5	271.5	
200	3	0	0	4.5	272.6	0	4.5	271.3	
400	7	0	0	4.5	271.7	0	4.5	264.0	
600	10	0	0	4.5	268.4	0	4.5	254.2	
800	13	0	0	4.5	264.7	0	4.5	245.1	
1000	17	0	0	4.5	260.7	0	4.5	236.6	
1204	20	0	0	4.5	256.2	0	4.5	228.1	
1405	23	0	0	4.5	251.8	0	4.5	220.2	
1607	27	0	0	4.5	247.7	0	4.5	212.5	
1811	30	1	0	4.5	243.9	0	4.5	205.4	Start of Recirculation Phase
3216	54	1	0	7.75	220.0	0	7.75	180.0	
4620	77	1	0	7.75	200.0	0	7.75	175.0	
6023	100	2	0	7.75	190.0	0	7.75	170.0	
7427	124	2	0	7.75	180.0	0	7.75	165.0	
8832	147	2	0	7.75	170.0	0	7.75	160.0	
10035	167	3	0	7.75	165.0	0	7.75	155.0	
11036	184	3	0	7.75	160.0	0	7.75	150.0	
13036	217	4	0	7.75	148.0	0	7.75	145.0	
14037	234	4	0	7.75	135.0	0	7.75	140.0	
46049	767	13	1	7.75	120.0	0	7.75	135.0	
86077	1435	24	1	7.74	115.0	0	7.74	130.0	
170089	2835	47	2	7.73	110.0	0	7.73	120.0	
260097	4335	72	3	7.73	110.0	0	7.73	115.0	
350108	5835	97	4	7.72	110.0	0	7.72	110.0	
430123	7169	119	5	7.71	110.0	0	7.71	105.0	
860168	14336	239	10	7.67	110.0	0	7.67	98.0	
1295340	21589	360	15	7.63	110.0	0	7.63	92.0	
1728000	28800	480	20	7.58	110.0	0	7.58	90.0	
2160000	36000	600	25	7.54	110.0	0	7.54	90.0	
2592000	43200	720	30	7.50	110.0	0	7.5	90.0	

Maximum ph, Minimum Temperature Data Continued

[Source: Min Water Vol, Max pH, Min Sump Temperature.xlsx]

Class	Material	Amount	Notes
Coolant	Sump Pool Volume (ft3)	62879	Should run sensitivities with both maximum and minimum
Metallic Aluminum	Aluminum Submerged (sq ft)	0	
	Aluminum Submerged (lbm)	0	
	Aluminum Not-Submerged (sq ft)	275	
	Aluminum Not-Submerged (lbm)	1000000	
Calcium Silicate	Marinite Insulation(ft3)	0.5	Other class members include Marinite and MUDD
	Asbestos Insulation (ft3)	0	
	Kaylo Insulation (ft3)	0	
	Unibestos Insulation (ft3)	0	
E-glass	Fiberglass Insulation (ft3)	225	
	NUKON (ft3)	400	
	Temp-Mat (ft3)	35	
	Thermal Wrap (ft3)	500	
Silica Powder	Microtherm (ft3)	0	
	Min-K (ft3)	0	
Mineral Wool	Min-Wool (ft3)	127.57	Removed SDC Line Mineral Wool (42.43 ft^3)
	Rock Wool (ft3)	0	
Aluminum Silicate	Cerablanket (ft3)	0	
	FiberFrax Durablanket (ft3)	0	
	Kaowool (ft3)	0	
	Mat-Ceramic (ft3)	0	
	Mineral Fiber (ft3)	0	
	PAROC Mineral Wool (ft3)	0	
Concrete	Concrete (ft2)	66300	
Trisodium Phosphate (TSP)	Trisodium Phosphate Hydrate (lbm)	0	Flag=0 if no TSP, ≠0 if use TSP as buffering agent
Interam	Interam (ft3)	0	

Class	Material	Amount	Density (lb/ft3)	Mass(kg)	Class total (kg)
Coolant	Sump Pool Volume (ft3)	62879	60.2	1717008.0	1717008.0
Metallic Aluminum	Aluminum Submerged (sq ft)	0.00		0.0	453597.0
	Aluminum Submerged (lbm)	0.00		0.0	
	Aluminum Not-Submerged (sq ft)	275		0.0	
	Aluminum Not-Submerged (lbm)	1000000		453597.0	
Calcium Silicate	Marinite Insulation(ft3)	0.5	46	10.4	10.4
	Asbestos Insulation (ft3)	0	14.5	0.0	
	Kaylo Insulation (ft3)	0	14.5	0.0	
	Unibestos Insulation (ft3)	0	14.5	0.0	
E-glass	Fiberglass Insulation (ft3)	225	5.5	561.3	1728.4
	NUKON (ft3)	400	2.4	435.5	
	Temp-Mat (ft3)	35	11.8	187.3	
	Thermal Wrap (ft3)	500	2.4	544.3	
Silica Powder	Microtherm (ft3)	0	4	0.0	0.0
	Min-K (ft3)	0	4	0.0	
Mineral Wool	Min-Wool (ft3)	127.57	8	462.9	462.9
	Rock Wool (ft3)	0	10	0.0	
Aluminum Silicate	Cerablanket (ft^3)	0	12	0.0	0.0
	FiberFrax Durablanket (ft3)	0	12	0.0	
	Kaowool (ft3)	0	12	0.0	
	Mat-Ceramic (ft3)	0	12	0.0	
	Mineral Fiber (ft3)	0	21	0.0	
	PAROC Mineral Wool (ft3)	0	21	0.0	
Concrete	Concrete (ft2)	66300		0.666845	0.6668454
Interam	Interam (ft3)	0	54	0.0	0.0

Maximum ph, Minimum Temperature Results

[Source: Min Water Vol, Max pH, Min Sump Temperature.xlsx]

Interval Duration (min)	Start of Interval (hrs)	End of Interval (hrs)	Average Interval pH	Average Temp (F)	Ca Release (kg)	Si Release (kg)	Al Release (kg)	$NaAlSi_3O_8$ Precipitate (kg)	AlOOH Precipitate (kg)	$Ca_3(PO_4)_2$ Precipitate (kg)	
0.4	0.00	0.0	4.5	207.471	0.0130	0.0156	0.0014	0.014	0.000	0.000	
0.5	0.01	0.0	4.5	253.873	0.04	0.07	0.01	0.1	0.0	0.00	
1.0	0.02	0.0	4.5	269.1365	0.09	0.22	0.02	0.2	0.0	0.00	
1.0	0.03	0.1	4.5	271.4485	0.14	0.37	0.04	0.4	0.0	0.00	
0.3	0.05	0.1	4.5	272.4435	0.16	0.42	0.05	0.5	0.0	0.00	
3.3	0.06	0.1	4.5	272.1795	0.33	0.94	0.11	1.0	0.0	0.00	
3.3	0.11	0.2	4.5	270.0695	0.50	1.43	0.16	1.6	0.0	0.00	
3.3	0.17	0.2	4.5	266.561	0.66	1.89	0.21	2.0	0.0	0.00	
3.3	0.22	0.3	4.5	262.6905	0.82	2.31	0.25	2.4	0.0	0.00	
3.4	0.28	0.3	4.5	258.4355	0.98	2.71	0.28	2.8	0.0	0.00	
3.3	0.33	0.4	4.5	254.024	1.13	3.06	0.31	3.0	0.0	0.00	
3.4	0.39	0.4	4.5	249.7725	1.27	3.39	0.34	3.3	0.0	0.00	
3.4	0.45	0.5	4.5	245.817	1.41	3.69	0.36	3.5	0.0	0.00	
23.4	0.50	0.9	6.125	231.962	2.39	6.52	0.55	5.3	0.0	0.00	
23.4	0.89	1.3	7.749932215	210	3.31	9.63	0.71	6.9	0.0	0.00	
23.4	1.28	1.7	7.749796651	195	4.10	11.74	0.81	7.9	0.0	0.00	
23.4	1.67	2.1	7.749661077	185	4.80	13.34	0.87	8.5	0.0	0.00	
23.4	2.06	2.5	7.74952546	175	5.42	14.54	0.92	8.9	0.0	0.00	
20.1	2.45	2.8	7.749399531	167.5	5.90	15.36	0.95	9.2	0.0	0.00	
16.7	2.79	3.1	7.749293135	162.5	6.27	15.95	0.97	9.4	0.0	0.00	
33.3	3.07	3.6	7.749148231	154	6.95	16.84	1.00	9.7	0.0	0.00	
16.7	3.62	3.9	7.749003308	141.5	7.23	17.13	1.01	9.8	0.0	0.00	
533.5	3.90	12.8	7.747409278	127.5	15.05	22.65	1.18	11.5	0.0	0.00	
667.1	12.79	23.9	7.743930816	117.5	19.72	26.24	1.34	13.0	0.0	0.00	
1400.2	23.91	47.2	7.737941528	112.5	24.07	30.71	1.60	15.5	0.0	0.00	
1500.1	47.25	72.2	7.729538925	110	24.08	33.07	1.84	17.9	0.0	0.00	
1500.2	72.25	97.3	7.720846669	110	24.10	34.58	2.07	20.2	0.0	0.00	
1333.6	97.25	119.5	7.712636928	110	24.12	35.45	2.27	22.1	0.0	0.00	
7167.4	119.48	238.9	7.688008571	110	24.20	38.36	3.28	31.9	0.0	0.00	
7252.9	238.94	359.8	7.646231384	110	24.28	38.95	4.18	40.6	0.0	0.00	
7211.0	359.82	480.0	7.60432793	110	24.37	39.54	4.96	48.2	0.0	0.00	
7200.0	480.00	600.0	7.562577637	110	24.46	39.79	5.65	54.9	0.0	0.00	
7200.0	600.00	720.0	7.520859212	110	24.54	39.84	6.26	60.9	0.0	0.00	KG
								134.2	0.00	0.00	LBS

Ca	Si	Al	
14.29336169	23.20271637	3.646123536	ppm

Releases in kg

Material Class	Ca	Si	Al
Metallic Aluminum Submerged	0.00	0.00	0.00
Metallic Aluminum Not-Submerged	0.00	0.00	0.43
Calcium Silicate	3.60	2.51	0.00
E-Glass	13.11	30.86	0.60
Silica Powder	0.00	0.00	0.00
Mineral Wool	7.31	6.16	5.22
Aluminum silicate	0.00	0.00	0.00
Concrete	0.52	0.31	0.00
Interam	0.00	0.00	0.00

Metallic Aluminum Not-Submerged		0.0%	6.9%
Calcium Silicate		6.3%	0.0%
E-Glass		77.5%	9.7%
Silica Powder		0.0%	0.0%
Mineral Wool		15.5%	83.4%
Aluminum silicate		0.0%	0.0%
Concrete		0.8%	0.1%

Minimum ph, Maximum Temperature Data

[Source: Max Water Vol, Min pH, Max Sump Temperature.xlsx]

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Sump Mixed 1=Yes	Steam or Spray pH	Containment Temp. (°F)	Notes
6	0	0	0	4.5	174.8	0	4.5	248.0	RCS blowdown
30	0.5	0	0	4.5	240.1	0	4.5	262.4	
60	1.0	0	0	4.5	267.6	0	4.5	271.3	
120	2	0	0	4.5	270.6	0	4.5	269.1	
180	3	0	0	4.5	272.3	0	4.5	271.5	
200	3	0	0	4.5	272.6	0	4.5	271.3	
400	7	0	0	4.5	271.7	0	4.5	264.0	
600	10	0	0	4.5	268.4	0	4.5	254.2	
800	13	0	0	4.5	264.7	0	4.5	245.1	
1000	17	0	0	4.5	260.7	0	4.5	236.6	
1204	20	0	0	4.5	256.2	0	4.5	228.1	
1405	23	0	0	4.5	251.8	0	4.5	220.2	
1607	27	0	0	4.5	247.7	0	4.5	212.5	
1811	30	1	0	4.5	243.9	0	4.5	205.4	Start of Recirculation Phase
3216	54	1	0	7.20	223.9	0	7.2	188.9	
4620	77	1	0	7.20	212.2	0	7.20	186.3	
6023	100	2	0	7.20	209.6	0	7.20	184.9	
7427	124	2	0	7.20	208.0	0	7.20	189.0	
8832	147	2	0	7.20	206.7	0	7.20	189.5	
10035	167	3	0	7.20	205.8	0	7.20	188.7	
11036	184	3	0	7.20	205.0	0	7.20	188.0	
13036	217	4	0	7.20	203.6	0	7.20	187.1	
14037	234	4	0	7.20	202.9	0	7.20	186.7	
46049	767	13	1	7.20	187.6	0	7.20	168.5	
86077	1435	24	1	7.19	175.2	0	7.19	156.3	
170089	2835	47	2	7.19	171.4	0	7.19	148.5	
260097	4335	72	3	7.18	168.5	0	7.18	143.8	
350108	5835	97	4	7.17	164.9	0	7.17	138.9	
430123	7169	119	5	7.17	161.6	0	7.17	134.1	
860168	14336	239	10	7.13	153.6	0	7.13	123.1	
1295340	21589	360	15	7.10	145.2	0	7.10	113.4	
1728000	28800	480	20	7.07	140.8	0	7.07	110.0	
2160000	36000	600	25	7.03	140.8	0	7.03	110.0	
2592000	43200	720	30	7.00	140.8	0	7	110.0	

Minimum ph, Maximum Temperature Data Continued

[Source: Max Water Vol, Min pH, Max Sump Temperature.xlsx]

Class	Material	Amount	Notes
Coolant	Sump Pool Volume (ft3)	76550.76	Should run sensitivities with both maximum and minimum
Metallic Aluminum	Aluminum Submerged (sq ft)	0	
	Aluminum Submerged (lbm)	0	
	Aluminum Not-Submerged (sq ft)	275	
	Aluminum Not-Submerged (lbm)	1000000	
Calcium Silicate	Marinite Insulation(ft3)	0.5	Other class members include Marinite and MUDD
	Asbestos Insulation (ft3)	0	
	Kaylo Insulation (ft3)	0	
	Unibestos Insulation (ft3)	0	
E-glass	Fiberglass Insulation (ft3)	225	
	NUKON (ft3)	400	
	Temp-Mat (ft3)	35	
	Thermal Wrap (ft3)	500	
Silica Powder	Microtherm (ft3)	0	
	Min-K (ft3)	0	
Mineral Wool	Min-Wool (ft3)	127.57	Removed SDC Line Mineral Wool (42.43 ft^3)
	Rock Wool (ft3)	0	
Aluminum Silicate	Cerablanket (ft3)	0	
	FiberFrax Durablanket (ft3)	0	
	Kaowool (ft3)	0	
	Mat-Ceramic (ft3)	0	
	Mineral Fiber (ft3)	0	
	PAROC Mineral Wool (ft3)	0	
Concrete	Concrete (ft2)	66300	
Trisodium Phosphate (TSP)	Trisodium Phosphate Hydrate (lbm)	0	Flag=0 if no TSP, ≠0 if use TSP as buffering agent
Interam	Interam (ft3)	0	

Class	Material	Amount	Density (lb/ft3)	Mass(kg)	Class total (kg)
Coolant	Sump Pool Volume (ft3)	76550.76	60.2	2090336.5	2090336.5
Metallic Aluminum	Aluminum Submerged (sq ft)	0.00		0.0	453597.0
	Aluminum Submerged (lbm)	0.00		0.0	
	Aluminum Not-Submerged (sq ft)	275		0.0	
	Aluminum Not-Submerged (lbm)	1000000		453597.0	
Calcium Silicate	Marinite Insulation(ft3)	0.5	46	10.4	10.4
	Asbestos Insulation (ft3)	0	14.5	0.0	
	Kaylo Insulation (ft3)	0	14.5	0.0	
	Unibestos Insulation (ft3)	0	14.5	0.0	
E-glass	Fiberglass Insulation (ft3)	225	5.5	561.3	1728.4
	NUKON (ft3)	400	2.4	435.5	
	Temp-Mat (ft3)	35	11.8	187.3	
	Thermal Wrap (ft3)	500	2.4	544.3	
Silica Powder	Microtherm (ft3)	0	4	0.0	0.0
	Min-K (ft3)	0	4	0.0	
Mineral Wool	Min-Wool (ft3)	127.57	8	462.9	462.9
	Rock Wool (ft3)	0	10	0.0	
Aluminum Silicate	Cerablanket (ft^3)	0	12	0.0	0.0
	FiberFrax Durablanket (ft3)	0	12	0.0	
	Kaowool (ft3)	0	12	0.0	
	Mat-Ceramic (ft3)	0	12	0.0	
	Mineral Fiber (ft3)	0	21	0.0	
	PAROC Mineral Wool (ft3)	0	21	0.0	
Concrete	Concrete (ft2)	66300		0.666845	0.6668454
Interam	Interam (ft3)	0	54	0.0	0.0

Minimum ph, Maximum Temperature Results

[Source: Max Water Vol, Min pH, Max Sump Temperature.xlsx]

Interval Duration (min)	Start of Interval (hrs)	End of Interval (hrs)	Average Interval pH	Average Temp (F)	Ca Release (kg)	Si Release (kg)	Al Release (kg)	$NaAlSi_3O_8$ Precipitate (kg)	AlOOH Precipitate (kg)	$Ca_3(PO_4)_2$ Precipitate (kg)	
0.4	0.00	0.0	4.5	207.471	0.0130	0.0156	0.0014	0.014	0.000	0.000	
0.5	0.01	0.0	4.5	253.873	0.04	0.07	0.01	0.1	0.0	0.00	
1.0	0.02	0.0	4.5	269.1365	0.09	0.22	0.02	0.2	0.0	0.00	
1.0	0.03	0.1	4.5	271.4485	0.14	0.37	0.04	0.4	0.0	0.00	
0.3	0.05	0.1	4.5	272.4435	0.16	0.42	0.05	0.5	0.0	0.00	
3.3	0.06	0.1	4.5	272.1795	0.33	0.94	0.11	1.0	0.0	0.00	
3.3	0.11	0.2	4.5	270.0695	0.50	1.43	0.16	1.6	0.0	0.00	
3.3	0.17	0.2	4.5	266.561	0.67	1.89	0.21	2.0	0.0	0.00	
3.3	0.22	0.3	4.5	262.6905	0.83	2.32	0.25	2.4	0.0	0.00	
3.4	0.28	0.3	4.5	258.4355	0.98	2.71	0.28	2.8	0.0	0.00	
3.3	0.33	0.4	4.5	254.024	1.13	3.07	0.32	3.1	0.0	0.00	
3.4	0.39	0.4	4.5	249.7725	1.27	3.40	0.34	3.3	0.0	0.00	
3.4	0.45	0.5	4.5	245.817	1.41	3.70	0.37	3.5	0.0	0.00	
23.4	0.50	0.9	5.85	233.9115	2.40	6.37	0.55	5.3	0.0	0.00	
23.4	0.89	1.3	7.199945772	218.0395	3.34	9.44	0.72	7.0	0.0	0.00	
23.4	1.28	1.7	7.199837321	210.89	4.21	11.99	0.86	8.3	0.0	0.00	
23.4	1.67	2.1	7.199728862	208.8025	5.04	14.38	0.98	9.6	0.0	0.00	
23.4	2.06	2.5	7.199620368	207.3755	5.84	16.66	1.10	10.7	0.0	0.00	
20.1	2.45	2.8	7.199519625	206.262	6.50	18.54	1.19	11.6	0.0	0.00	
16.7	2.79	3.1	7.199434508	205.392	7.03	20.05	1.27	12.3	0.0	0.00	
33.3	3.07	3.6	7.199318585	204.281	8.06	22.95	1.41	13.7	0.0	0.00	
16.7	3.62	3.9	7.199202647	203.2185	8.55	24.34	1.48	14.4	0.0	0.00	
533.5	3.90	12.8	7.197927422	195.2205	22.86	59.97	3.07	29.8	0.0	0.00	
667.1	12.79	23.9	7.195144653	181.3825	28.85	79.92	3.88	37.8	0.0	0.00	
1400.2	23.91	47.2	7.190353222	173.2835	33.44	98.95	4.93	48.0	0.0	0.00	
1500.1	47.25	72.2	7.18363114	169.931	35.51	104.46	5.83	56.7	0.0	0.00	
1500.2	72.25	97.3	7.176677336	166.7205	36.58	105.03	6.56	63.8	0.0	0.00	
1333.6	97.25	119.5	7.170109542	163.28	36.90	105.41	7.08	68.8	0.0	0.00	
7167.4	119.48	238.9	7.150406857	157.605	37.07	105.49	9.26	90.0	0.0	0.00	
7252.9	238.94	359.8	7.116985107	149.3775	37.23	105.57	10.34	100.5	0.0	0.00	
7211.0	359.82	480.0	7.083462344	143.0025	37.38	105.64	10.96	106.5	0.0	0.00	
7200.0	480.00	600.0	7.05006211	140.841	37.52	105.70	11.39	110.8	0.0	0.00	
7200.0	600.00	720.0	7.01668737	140.841	37.66	105.77	11.71	113.8	0.0	0.00	KG
								251.0	0.00	0.00	LBS

Ca	Si	Al	
18.01598889	50.60058955	5.602581505	ppm

Releases in kg

Material Class	Ca	Si	Al
Metallic Aluminum Submerged	0.00	0.00	0.00
Metallic Aluminum Not-Submerged	0.00	0.00	0.96
Calcium Silicate	3.60	2.51	0.00
E-Glass	20.16	89.35	1.78
Silica Powder	0.00	0.00	0.00
Mineral Wool	12.94	13.46	8.95
Aluminum silicate	0.00	0.00	0.00
Concrete	0.96	0.45	0.02
Interam	0.00	0.00	0.00

Metallic Aluminum Not-Submerged		0.0%	8.2%
Calcium Silicate		2.4%	0.0%
E-Glass		84.5%	15.2%
Silica Powder		0.0%	0.0%
Mineral Wool		12.7%	76.4%
Aluminum silicate		0.0%	0.0%
Concrete		0.4%	0.2%

Minimum ph, Minimum Temperature Data

[Source: Max Water Vol, Min pH, Min Sump Temperature.xlsx]

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Sump Mixed 1=Yes	Steam or Spray pH	Containment Temp. (°F)	Notes
6	0	0	0	4.5	174.8	0	4.5	248.0	RCS blowdown
30	0.5	0	0	4.5	240.1	0	4.5	262.4	
60	1.0	0	0	4.5	267.6	0	4.5	271.3	
120	2	0	0	4.5	270.6	0	4.5	269.1	
180	3	0	0	4.5	272.3	0	4.5	271.5	
200	3	0	0	4.5	272.6	0	4.5	271.3	
400	7	0	0	4.5	271.7	0	4.5	264.0	
600	10	0	0	4.5	268.4	0	4.5	254.2	
800	13	0	0	4.5	264.7	0	4.5	245.1	
1000	17	0	0	4.5	260.7	0	4.5	236.6	
1204	20	0	0	4.5	256.2	0	4.5	228.1	
1405	23	0	0	4.5	251.8	0	4.5	220.2	
1607	27	0	0	4.5	247.7	0	4.5	212.5	
1811	30	1	0	4.5	243.9	0	4.5	205.4	Start of Recirculation Phase
3216	54	1	0	7.20	220.0	0	7.2	180.0	
4620	77	1	0	7.20	200.0	0	7.20	175.0	
6023	100	2	0	7.20	190.0	0	7.20	170.0	
7427	124	2	0	7.20	180.0	0	7.20	165.0	
8832	147	2	0	7.20	170.0	0	7.20	160.0	
10035	167	3	0	7.20	165.0	0	7.20	155.0	
11036	184	3	0	7.20	160.0	0	7.20	150.0	
13036	217	4	0	7.20	148.0	0	7.20	145.0	
14037	234	4	0	7.20	135.0	0	7.20	140.0	
46049	767	13	1	7.20	120.0	0	7.20	135.0	
86077	1435	24	1	7.19	115.0	0	7.19	130.0	
170089	2835	47	2	7.19	110.0	0	7.19	120.0	
260097	4335	72	3	7.18	110.0	0	7.18	115.0	
350108	5835	97	4	7.17	110.0	0	7.17	110.0	
430123	7169	119	5	7.17	110.0	0	7.17	105.0	
860168	14336	239	10	7.13	110.0	0	7.13	98.0	
1295340	21589	360	15	7.10	110.0	0	7.10	92.0	
1728000	28800	480	20	7.07	110.0	0	7.07	90.0	
2160000	36000	600	25	7.03	110.0	0	7.03	90.0	
2592000	43200	720	30	7.00	110.0	0	7	90.0	

Minimum ph, Minimum Temperature Data Continued

[Source: Max Water Vol, Min pH, Min Sump Temperature.xlsx]

Class	Material	Amount	Notes
Coolant	Sump Pool Volume (ft3)	76550.76	Should run sensitivities with both maximum and minimum
Metallic Aluminum	Aluminum Submerged (sq ft)	0	
	Aluminum Submerged (lbm)	0	
	Aluminum Not-Submerged (sq ft)	275	
	Aluminum Not-Submerged (lbm)	1000000	
Calcium Silicate	Marinite Insulation(ft3)	0.5	Other class members include Marinite and MUDD
	Asbestos Insulation (ft3)	0	
	Kaylo Insulation (ft3)	0	
	Unibestos Insulation (ft3)	0	
E-glass	Fiberglass Insulation (ft3)	225	
	NUKON (ft3)	400	
	Temp-Mat (ft3)	35	
	Thermal Wrap (ft3)	500	
Silica Powder	Microtherm (ft3)	0	
	Min-K (ft3)	0	
Mineral Wool	Min-Wool (ft3)	127.57	Removed SDC Line Mineral Wool (42.43 ft^3)
	Rock Wool (ft3)	0	
Aluminum Silicate	Cerablanket (ft3)	0	
	FiberFrax Durablanket (ft3)	0	
	Kaowool (ft3)	0	
	Mat-Ceramic (ft3)	0	
	Mineral Fiber (ft3)	0	
	PAROC Mineral Wool (ft3)	0	
Concrete	Concrete (ft2)	66300	
Trisodium Phosphate (TSP)	Trisodium Phosphate Hydrate (lbm)	0	Flag=0 if no TSP, ≠0 if use TSP as buffering agent
Interam	Interam (ft3)	0	

Class	Material	Amount	Density (lb/ft3)	Mass(kg)	Class total (kg)
Coolant	Sump Pool Volume (ft3)	76550.76	60.2	2090336.5	2090336.5
Metallic Aluminum	Aluminum Submerged (sq ft)	0.00		0.0	453597.0
	Aluminum Submerged (lbm)	0.00		0.0	
	Aluminum Not-Submerged (sq ft)	275		0.0	
	Aluminum Not-Submerged (lbm)	1000000		453597.0	
Calcium Silicate	Marinite Insulation(ft3)	0.5	46	10.4	10.4
	Asbestos Insulation (ft3)	0	14.5	0.0	
	Kaylo Insulation (ft3)	0	14.5	0.0	
	Unibestos Insulation (ft3)	0	14.5	0.0	
E-glass	Fiberglass Insulation (ft3)	225	5.5	561.3	1728.4
	NUKON (ft3)	400	2.4	435.5	
	Temp-Mat (ft3)	35	11.8	187.3	
	Thermal Wrap (ft3)	500	2.4	544.3	
Silica Powder	Microtherm (ft3)	0	4	0.0	0.0
	Min-K (ft3)	0	4	0.0	
Mineral Wool	Min-Wool (ft3)	127.57	8	462.9	462.9
	Rock Wool (ft3)	0	10	0.0	
Aluminum Silicate	Cerablanket (ft^3)	0	12	0.0	0.0
	FiberFrax Durablanket (ft3)	0	12	0.0	
	Kaowool (ft3)	0	12	0.0	
	Mat-Ceramic (ft3)	0	12	0.0	
	Mineral Fiber (ft3)	0	21	0.0	
	PAROC Mineral Wool (ft3)	0	21	0.0	
Concrete	Concrete (ft2)	66300		0.666845	0.6668454
Interam	Interam (ft3)	0	54	0.0	0.0

Minimum ph, Minimum Temperature Results

[Source: Max Water Vol, Min pH, Min Sump Temperature.xlsx]

Interval Duration (min)	Start of Interval (hrs)	End of Interval (hrs)	Average Interval pH	Average Temp (F)	Ca Release (kg)	Si Release (kg)	Al Release (kg)	$NaAlSi_3O_8$ Precipitate (kg)	AlOOH Precipitate (kg)	$Ca_3(PO_4)_2$ Precipitate (kg)	
0.4	0.00	0.0	4.5	207.471	0.0130	0.0156	0.0014	0.014	0.000	0.000	
0.5	0.01	0.0	4.5	253.873	0.04	0.07	0.01	0.1	0.0	0.00	
1.0	0.02	0.0	4.5	269.1365	0.09	0.22	0.02	0.2	0.0	0.00	
1.0	0.03	0.1	4.5	271.4485	0.14	0.37	0.04	0.4	0.0	0.00	
0.3	0.05	0.1	4.5	272.4435	0.16	0.42	0.05	0.5	0.0	0.00	
3.3	0.06	0.1	4.5	272.1795	0.33	0.94	0.11	1.0	0.0	0.00	
3.3	0.11	0.2	4.5	270.0695	0.50	1.43	0.16	1.6	0.0	0.00	
3.3	0.17	0.2	4.5	266.561	0.67	1.89	0.21	2.0	0.0	0.00	
3.3	0.22	0.3	4.5	262.6905	0.83	2.32	0.25	2.4	0.0	0.00	
3.4	0.28	0.3	4.5	258.4355	0.98	2.71	0.28	2.8	0.0	0.00	
3.3	0.33	0.4	4.5	254.024	1.13	3.07	0.32	3.1	0.0	0.00	
3.4	0.39	0.4	4.5	249.7725	1.27	3.40	0.34	3.3	0.0	0.00	
3.4	0.45	0.5	4.5	245.817	1.41	3.70	0.37	3.5	0.0	0.00	
23.4	0.50	0.9	5.85	231.962	2.38	6.26	0.54	5.2	0.0	0.00	
23.4	0.89	1.3	7.199945772	210	3.27	8.80	0.67	6.5	0.0	0.00	
23.4	1.28	1.7	7.199837321	195	4.03	10.54	0.75	7.3	0.0	0.00	
23.4	1.67	2.1	7.199728862	185	4.71	11.86	0.80	7.8	0.0	0.00	
23.4	2.06	2.5	7.199620368	175	5.32	12.87	0.84	8.2	0.0	0.00	
20.1	2.45	2.8	7.199519625	167.5	5.79	13.56	0.87	8.4	0.0	0.00	
16.7	2.79	3.1	7.199434508	162.5	6.16	14.05	0.88	8.6	0.0	0.00	
33.3	3.07	3.6	7.199318585	154	6.82	14.81	0.91	8.8	0.0	0.00	
16.7	3.62	3.9	7.199202647	141.5	7.11	15.06	0.92	8.9	0.0	0.00	
533.5	3.90	12.8	7.197927422	127.5	15.02	19.95	1.07	10.4	0.0	0.00	
667.1	12.79	23.9	7.195144653	117.5	20.45	23.45	1.19	11.6	0.0	0.00	
1400.2	23.91	47.2	7.190353222	112.5	25.57	28.30	1.41	13.7	0.0	0.00	
1500.1	47.25	72.2	7.18363114	110	25.81	31.44	1.62	15.7	0.0	0.00	
1500.2	72.25	97.3	7.176677336	110	25.84	33.71	1.81	17.6	0.0	0.00	
1333.6	97.25	119.5	7.170109542	110	25.86	35.17	1.98	19.2	0.0	0.00	
7167.4	119.48	238.9	7.150406857	110	25.95	40.91	2.85	27.7	0.0	0.00	
7252.9	238.94	359.8	7.116985107	110	26.05	41.53	3.63	35.3	0.0	0.00	
7211.0	359.82	480.0	7.083462344	110	26.14	42.14	4.33	42.1	0.0	0.00	
7200.0	480.00	600.0	7.05006211	110	26.23	42.28	4.96	48.2	0.0	0.00	
7200.0	600.00	720.0	7.01668737	110	26.33	42.33	5.53	53.7	0.0	0.00	KG
								118.5	0.00	0.00	LBS

Ca	Si	Al	
12.59480746	20.25019194	2.645378597	ppm

	Releases in kg		
Material Class	Ca	Si	Al
Metallic Aluminum Submerged	0.00	0.00	0.00
Metallic Aluminum Not-Submerged	0.00	0.00	0.32
Calcium Silicate	3.60	2.51	0.00
E-Glass	14.64	33.30	0.56
Silica Powder	0.00	0.00	0.00
Mineral Wool	7.52	6.21	4.65
Aluminum silicate	0.00	0.00	0.00
Concrete	0.57	0.31	0.00
Interam	0.00	0.00	0.00

Metallic Aluminum Not-Submerged		0.0%	5.7%
Calcium Silicate		5.9%	0.0%
E-Glass		78.7%	10.1%
Silica Powder		0.0%	0.0%
Mineral Wool		14.7%	84.1%
Aluminum silicate		0.0%	0.0%
Concrete		0.7%	0.1%

ATTACHMENT (2)

ECCS and CS SYSTEM FIGURES

FIGURE 6-1 SAFETY INJECTION AND CONTAINMENT SPRAY – UNIT 1

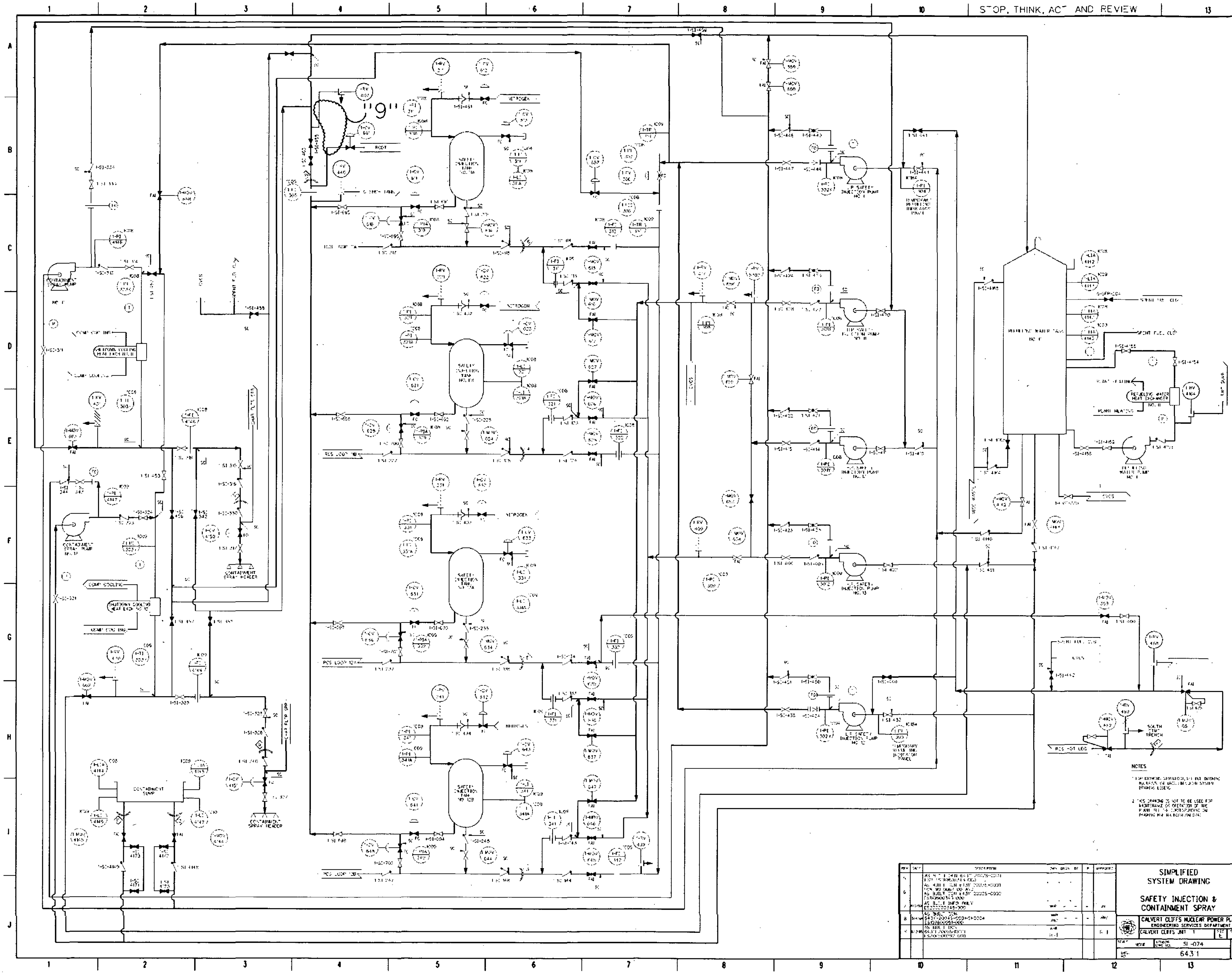


FIGURE 6-10 SAFETY INJECTION AND CONTAINMENT SPRAY – UNIT 2