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10 CFR 50.54(f)

RS-07-161
December 31, 2007

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

Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

References:

(1) Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004

(2) Letter from K. R. Jury (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U. S. Nuclear Regulatory Commission "Exelon/AmerGen Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,'" dated March 7, 2005

(3) Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U. S. Nuclear Regulatory Commission "Exelon/AmerGen Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,'" dated September 1, 2005

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(4) Letter from M. L. Chawla (U. S. Nuclear Regulatory Commission) to C. M. Crane (Exelon Generation Company, LLC), "Braidwood Station, Unit Nos. 1 and 2 – Request for Additional Information Re: Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors,'" dated February 9, 2006

(5) Letter from M. L. Chawla (U. S. Nuclear Regulatory Commission) to C. M. Crane (Exelon Generation Company, LLC), "Byron Station, Unit Nos. 1 and 2 – Request for Additional Information Re: Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors,'" dated February 9, 2006

(6) Letter from K. R. Jury (Exelon Generation Company, LLC) to U. S. Nuclear Regulatory Commission, "Supplement to Exelon Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,'" dated May 31, 2006

(7) Letter from R. F. Kuntz (U. S. Nuclear Regulatory Commission) to C. M. Crane (Exelon Generation Company, LLC), "Byron Station, Unit No.1 and Braidwood Station, Unit 2 – Requested Extension of Completion Schedule for NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors,'" dated July 21, 2006

(8) Letter from C. T. Haney (U. S. Nuclear Regulatory Commission) to Holders of Operating Licenses for Pressurized Water Reactors, "Alternative Approach for Responding to the Nuclear Regulatory Commission Request for Additional Information Letter Regarding Generic Letter 2004-02," dated January 4, 2007

(9) Letter from W. H. Ruland (U. S. Nuclear Regulatory Commission) to A. Pietrangelo (Nuclear Energy Institute), "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," dated November 21, 2007

The purpose of this submittal is to provide the Exelon Generation Company, LLC (EGC) supplemental response to the Generic Letter (GL) 2004-02 (Reference 1). The U. S. Nuclear Regulatory Commission (NRC) issued Reference 1 to request that addressees perform an evaluation of the emergency core cooling system (ECCS) and containment spray system (CSS) recirculation functions in light of the information provided in the GL and, if appropriate, take additional actions to ensure system function.

Additionally, the GL requested addressees to provide the NRC with a written response in accordance with 10 CFR 50.54(f). The request was based on identified potential susceptibility of the pressurized water reactor (PWR) recirculation sump screens to debris blockage during design basis accidents requiring recirculation operation of ECCS or CSS and on the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and CSS recirculation and containment drainage.

Reference 2 provided the initial EGC response to the GL followed by a supplemental response in Reference 3. References 4 and 5 requested additional information regarding the Reference 3 response to the GL for Braidwood Station and Byron Station, respectively. Reference 6 requested an extension to the December 31, 2007 due date for completion of all GL required actions. This request was specific to Braidwood Station, Unit 2 and Byron Station, Unit 1 in order to complete installation and testing of modified ECCS throttle valves and CSS cyclone separators. In the Reference 6 request, EGC acknowledged that all other aspects of the required GL actions for these affected units would be complete by December 31, 2007, including the installation of new ECCS Sump strainers. The Reference 6 request also confirmed that all required GL actions for Braidwood Station, Unit 1 and Byron Station, Unit 2 would be completed prior to December 31, 2007. This request for an extension was approved in the Reference 7 evaluation.

Reference 8 provided an alternative approach for addressing all outstanding requests for additional information (i.e., References 4 and 5) including the expectation that all necessary responses would be provided by December 31, 2007. In accordance with this request, EGC is providing the necessary supplemental response, addressing GL actions at Braidwood and Byron Stations, in Attachment 1 to this letter. Attachment 2 provides diagrams to support the review of the Attachment 1 information. This response was prepared using the guidelines of Reference 9. This information is being provided in accordance with 10 CFR 50.54(f). There are no regulatory commitments provided in this submittal.

If you have any questions, please contact David J. Chrzanowski at (630) 657-2816.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 31st day of December 2007.

Respectfully,

Patrick R Simpson

Patrick R. Simpson
Manager - Licensing

Attachments: 1. Braidwood Station, Units 1 and 2 and Byron Station, Units 1 and 2, Supplemental Response to NRC Generic Letter 2004-02

2. Braidwood Station and Byron Station Emergency Core Cooling System Single Line Drawings

cc: NRC Regional Administrator - NRC Region III
NRC Senior Resident Inspector – Braidwood Station
NRC Senior Resident Inspector – Byron Station

Attachment 1

Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
<u>NRC Docket Nos. STN 50-456 and STN 50-457</u>

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
<u>NRC Docket Nos. STN 50-454 and STN 50-455</u>

Supplemental Response to NRC 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.

Exelon Generation Company, LLC (EGC) Response to Issue 1:

The recirculation functions for the Emergency Core Cooling Systems (ECCS) and the Containment Spray Systems (CSS) for Braidwood Station, Unit 1, and Byron Station, Unit 2, are in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of Generic Letter 2004-02 under debris loading conditions. Braidwood Station, Unit 2 and Byron Station, Unit 1 will be in compliance with the regulatory requirements with completion of downstream valve modifications to be completed during the refueling outages in Spring 2008.

The Braidwood Station (Braidwood) licensing basis and the Byron Station (Byron) licensing basis have been updated to reflect the results of the analyses and the modifications performed to demonstrate compliance with the regulatory requirements. This update was performed in accordance with the requirements of 10 CFR 50.71. There were no licensing actions or exemption requests needed to support changes to the plant-licensing basis as a result of the GSI-191 improvements.

At Braidwood and Byron, two emergency recirculation sumps (ECCS Sumps) are provided for each unit. Each ECCS Sump serves one train of the ECCS and the CSS. In response to Generic Letter (GL) 2004-02, the ECCS Sump screens have been replaced. The surface area for the recirculation sumps has been increased from approximately 260 ft^2 for both sumps to over 3,000 ft^2 for each ECCS Sump. The replacement screens have been manufactured by Control Components Inc. (CCI) and have a nominal hole size of 1/12" compared to the previous screens' openings of 3/8" mesh size. Each screen assembly is fully enclosed in the ECCS Sump pit below the containment floor elevation of 377 ft. The screen assembly in each ECCS Sump pit is sized for the full design basis debris load.

A trash rack structure, four-ft high with stainless steel grating, has been installed at the containment floor elevation. The trash rack encloses the openings for both sumps.

The size of the replacement screens was determined based on the results of head loss testing at the vendor facilities in Switzerland. The Braidwood and Byron testing started in late 2005 and continued through the 1st half of 2006. Chemical effects head loss testing was completed in June 2006.

Braidwood and Byron can be characterized as Reflective Metal Insulation (RMI) plants. The initial debris generation analysis showed a significant quantity of fiberglass in the debris term due to the Transco Thermal Wrap insulation that was installed on the Braidwood and Byron Unit 1 Steam Generators and connected piping.

Head loss test results indicated that the fiber could not be absorbed in the design options that were available. For this reason, and to remove one of the more problematic debris types, the Thermal Wrap insulation was replaced (within its Zone Of Influence) with Transco RMI on the Unit 1 Steam Generators and connected piping. Outside of its Zone Of Influence (ZOI), Transco Thermal Wrap insulation remains installed on the Steam Generators and connected piping. Following the Unit 1 insulation change, the debris term for both units at Braidwood and Byron includes only RMI insulation debris at the ECCS Sump screens.

Other debris that reached the screens includes coatings (qualified and unqualified). The qualified coatings quantity for epoxy was determined based on a ZOI of 10 pipe diameters (i.e., 10D). This assumption results in a total epoxy quantity that is about seven times larger than the quantity that is calculated with a ZOI of 5D. Furthermore, 100% of unqualified coatings, regardless of types and location inside containment, were assumed to fail. All coatings were modeled with 10 μm particle sizes in the design basis head loss testing.

A large sacrificial area of 900 ft^2 was incorporated into the Braidwood and Byron design. The screen model that was tested for head loss was scaled from a total surface area that did not include the sacrificial area. The sacrificial area is assigned for labels, tags, and stickers. These items are assumed to fail per Nuclear Energy Institute 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," (i.e., the Guidance Report or GR) as endorsed in the "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), 'Pressurized Water Reactor Sump Performance Evaluation Methodology,'" issued December 6, 2004 (i.e., the SE).

The head loss due to debris in the filter pockets also includes the contribution of chemical effects. The testing used maximum ECCS Sump flow rates (due to Residual Heat Removal system and CSS pumps) and the chemical quantities that are calculated to be present in containment at 30-days following the event. Considering that Braidwood and Byron emergency procedures include steps to shutoff the CSS pumps at eight (8) hours after the event, the 30-day chemical quantity will be at the screen when the flow through the screen is about 50% of the design basis flow rate, thus resulting in lower head loss.

Head loss testing was performed based on accident flow rates that are higher than the calculated post-accident flow rates. Higher flow rates than calculated were also used in the friction loss analysis and the Net Positive Suction Head (NPSH) analysis for the Residual Heat Removal (RH) and CSS pumps. The NPSH required values were based on these larger flow rates. The NPSH analysis concluded that positive margins remain for the RH and CSS pumps when their suction is aligned to the ECCS Sump after a Loss of Coolant Accident (LOCA).

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.

EGC Response to Issue 2:

As of December 31, 2007, Braidwood and Byron Stations have completed the following Generic Letter 2004-02 actions, analyses and modifications.

- NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containment"
- Latent Debris Walkdowns
- Debris Generation Analysis
- Containment Debris Transport Analysis (includes Computational Fluid Dynamics)
- Head Loss Analysis
- Hydraulic Model of the ECCS System
- CSS and RH Net Positive Suction Head Analysis
- Vendor's Strainer Head Loss Testing
- Bypass testing
- Downstream Wear and Blockage Analysis
- Chemical Effects Testing (Bench Top and Head Loss Testing)
- ECCS Throttle Valves Wear and Blockage Testing
- CSS Cyclone Separator Blockage Testing
- Trash Rack Installation
- Detailed Structural Analysis of New Screens and Trash Racks
- Fiber insulation removal within the ZOI at Braidwood Unit 1 and Byron Unit 1
- ECCS Sump Strainers Replacement Modification Installed at Braidwood and at Byron
- ECCS Throttle Valves Modification Installed at Braidwood Unit 1 and Byron Unit 2.

EGC requested[1] and received approval[2] for an extension until Spring 2008 to complete the installation and testing of ECCS throttle valves and CSS cyclone separators for Braidwood, Unit 2 and Byron, Unit 1.

Testing was performed at Wyle Laboratories to determine if the cyclone separators that are installed on the mechanical seal flushing line for the CSS pumps at Braidwood and Byron are susceptible to blockage. The testing results show that the cyclone separators, as tested with the Braidwood and Byron design basis debris loading, are not susceptible to blockage. Therefore, modifications on these components are not needed.

Currently, Braidwood, Unit 1 and Byron, Unit 2 are in full compliance with the requirements of GL 2004-02. Following the Spring 2008 refueling outages, Braidwood Unit 2 and Byron Unit 1 will be in full compliance with the requirements of Generic Letter 2004-02.

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[1] Letter from K. R. Jury (Exelon Generation Company, LLC) to U. S. Nuclear Regulatory Commission "Supplement to Exelon Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,'" dated May 31, 2006

[2] Letter from R. F. Kuntz (U. S. Nuclear Regulatory Commission) to C. M. Crane (Exelon Generation Company, LLC, "Byron Station Unit No. 1, and Braidwood Station, Unit No. 2 - Requested Extension of Completion Schedule for NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,'" dated July 21, 2006

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.*

EGC Response to Issue 3a1:

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. Based on various postulated break locations, the following break locations were evaluated per the GR, as modified by the SE, to maximize the postulated debris created:

1. The interim leg at the inlet to the loop D reactor coolant pump (RCP) at approximate elevation 386'-0" is the largest postulated line in containment and will affect a large amount of reflective mirror insulation on the major equipment and piping inside the missile barrier. It also is the most direct path to the ECCS Sump. This is the limiting break for Braidwood and Byron since it has the greatest coating debris quantity, which dominates the fiber and particulate head loss. This coating debris quantity was then used for all break locations. This is identified as break location S1.

2. The loop A cold leg between the reactor coolant loop isolation valve and the reactor shield wall at elevation 393'-0" is chosen because it is another large break that will create a large amount of insulation debris. It is also located farther from the ECCS Sump, which will create a different transport path for debris. This is identified as break location S2.

3. The loop D hot leg between the loop stop valve and the reactor shield wall at elevation 393'-0" is chosen because it generates the largest amount of fiber debris in Unit 1 of Braidwood and Byron. This location was considered as part of the original break selection prior to the fiber insulation removal for Unit 1 at Braidwood and Byron. This is identified as break location S4.

4. An alternate break is evaluated at the 14" pressurizer surge line (branch off of the reactor coolant system loop D line) at the connection to the pressurizer. This break would damage the reflective mirror insulation on most piping in loop D and a small amount in loop A, with the exception of piping near the top of the pressurizer. The loop D RCP and pressurizer insulation would also be damaged. This is identified as break location S3.

The insulation for lines and equipment is nearly identical in all four units. The majority of the insulation is Mirror RMI. Sections for the steam generators (SGs) in Unit 1 for both Braidwood and Byron are insulated with Transco RMI and Transco Thermal Wrap, which is fiber insulation. The associated Braidwood and Byron Unit 1 SG piping connections (Main Steam, Feedwater, Auxiliary Feedwater, Steam Generator Blowdown) also have sections of Transco Thermal Wrap. In order to eliminate fiber insulation from the debris term, thermal wrap insulation that was located within its ZOI was replaced with reflective metal insulation for Braidwood, Unit 1 and Byron, Unit 1. The SGs in Braidwood, Unit 2 and Byron, Unit 2 are insulated entirely with RMI.

EGC Response to Issue 3a2:

For feedwater line breaks and main steam line breaks, recirculation from the ECCS Sump is not credited for Braidwood and Byron. Therefore, analysis of breaks in the main steam and feedwater lines were not performed in response to GL 2004-02.

EGC Response to Issue 3a3:

In summary,

Table 3a3 – 1
Break Summary

Break Name	Break ID	Elevation	Piping
S1	31"	386'-0"	Interim Leg – Loop D
S2	27 1/2"	393'-0"	Cold Leg – Loop A
S3	~11"	393'-0"	Alternate Break (Hot Leg D)
S4	29"	393'-0"	Hot Leg – Loop D

The quantities of debris that are transported to the ECCS Sump screen are provided in the following Table.

Table 3a3 - 2
Debris Transport Quantities

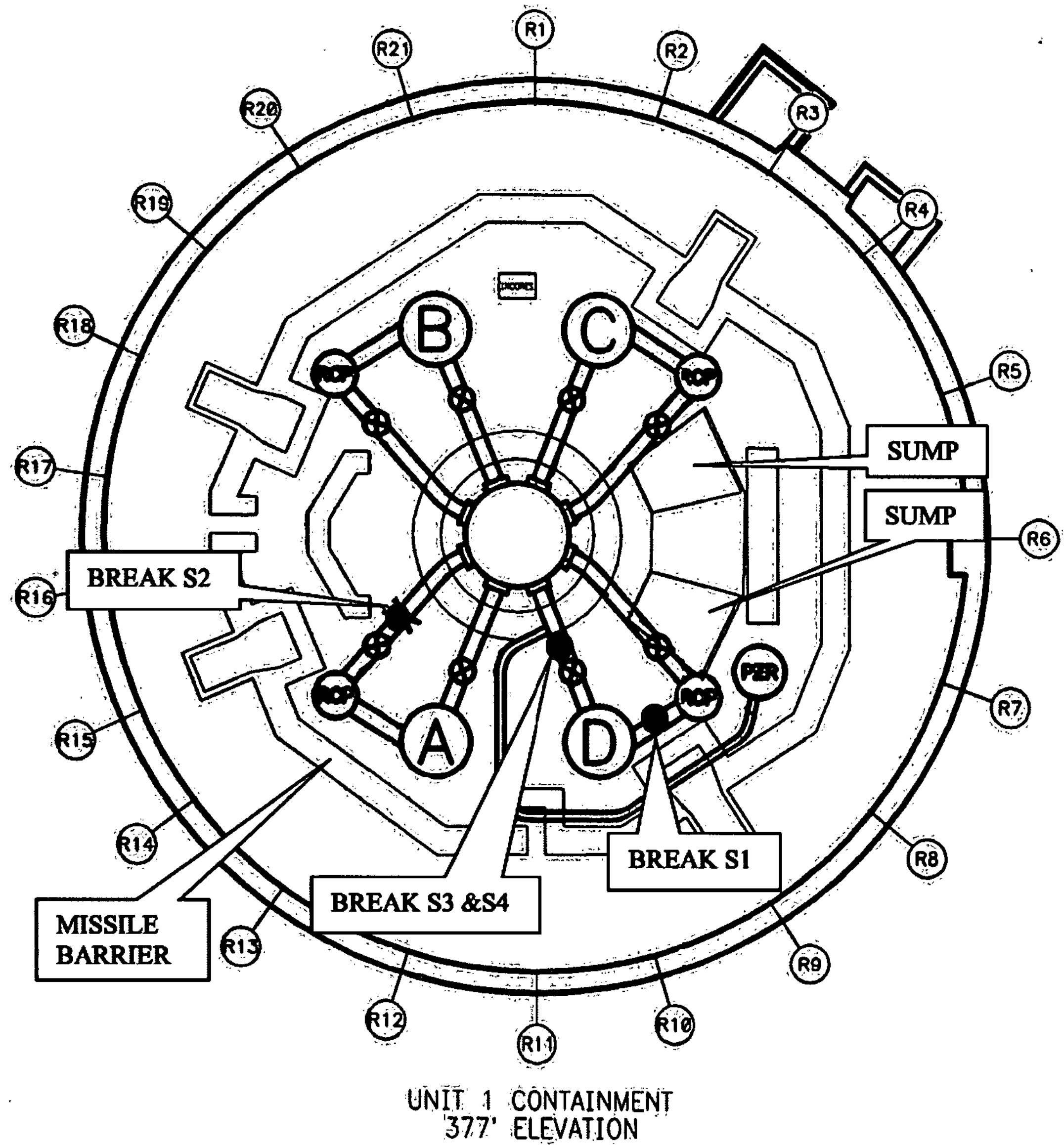
Debris Type	Units	Quantity Transported To ECCS Sump Screen	Quantity Documented for Strainer Head Loss Test
SS RMI Foil	[ft^2]	21,593	21,989
Qualified Coatings (epoxy/epoxy phenolic) 10D	[ft^3]	25.474	26.0
Qualified Coatings (inorganic zinc) 10D	[ft^3]	6.819	7.1
Unqualified Coatings	[ft^3]	12.20	12.8
Foreign Materials	[ft^2]	521	900
Light bulb glass	[ft^2]	84	88.7
Adhesive	[ft^3]	0.12	0.2
Latent Debris	[lbm]	150	150

Per the SE, Section 3.5.2.2.2, the sacrificial area caused by foreign materials is 75% of the total foreign materials surface area. Consequently, the value from the above table is 75% of the total value that was calculated to reach the screens.

The amount of sacrificial area that has been allotted to foreign materials or miscellaneous debris is 900 ft^2.

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.

Figure 3a3 – 1
Break Locations



NRC Issue 3b:

Debris Generation/Zone of Influence (ZOI) (excluding coatings)
The objective of the debris generation/ZOI 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 ZOIs for generating debris. Identify which debris analyses used approved methodology default values. For debris with ZOIs not defined in the guidance report (GR)/safety evaluation (SE), or if using other than default values, discuss method(s) used to determine ZOI and the basis for each.*
2. *Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.*
3. *Identify if destruction testing was conducted to determine ZOIs. 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.*

EGC Response to Issues 3b1 and 3b2:

The ZOIs for the insulation at Braidwood and Byron were applied using the criteria established in the SE and are listed below.

Table 3b1-1
Zones of Influence

Insulation	**ZOI Radius / Break Diameter (R/D)** (See Note 1)
Transco RMI	2.0
Tempmat	11.7
Nukon (Thermal-Wrap) (w/o Sure-Hold bands) (Fiber)	17.0 (See Note 2)
Reflective Mirror with Standard Bands	28.6

1. The center of the ZOI is at the location of the break.
2. The GR and the SE do not list a destruction pressure for Transco Thermal Wrap insulation. Material properties and manufacturer published data indicate a similarity between Thermal Wrap and NUKON (both being low density fiberglass). Therefore, the destruction pressure of Thermal Wrap will be taken as that of NUKON (i.e., 6 psi). This corresponds to a ZOI of 17D. As discussed above, all Transco Thermal-Wrap has since been removed from the ZOI at Braidwood, Unit 1 and Byron, Unit 1. The thermal wrap insulation consists of wire-bound fiberglass blankets, covered with stainless steel sheathing. The insulation sections are installed using support steel rings and buckles.

The types of insulation present on the piping and equipment inside the Braidwood and Byron containments are as follows.

Table 3b1-2
Insulation Types

Equipment/Piping	**Insulation Type**
Reactor Pressure Vessel	Mirror, Tempmat
Braidwood and Byron U1 S/G A/B/C/D	Transco RMI, Thermal-Wrap
Braidwood and Byron U2 S/G A/B/C/D	Mirror
Reactor Coolant Pumps	Mirror
Pressurizer	Mirror
Reactor Coolant System (RCS) piping	Mirror (Unit 1 has a small portion of Transco RMI on the Hot and Interim legs, but for simplicity and conservatism only Mirror will be used.)
Main Steam piping Byron, Unit 1	Mirror, Transco RMI, Thermal-wrap
Main Steam piping Braidwood, Unit 2	Mirror
Feedwater piping Byron, Unit 1	Mirror, Transco RMI
Feedwater piping Braidwood, Unit 2	Mirror
Recirculation (Unit 1)	Transco RMI
Auxiliary (Blowdown) Feedwater piping	Mirror
Safety Injection piping	Mirror
Residual Heat Removal (RH) piping	Mirror
S/G Blowdown piping	Mirror, Transco RMI
Pressurizer System piping	Mirror
Chemical and Volume Control (CVCS) piping	Mirror
Interim Leg Drain piping	Mirror

A hot leg or cold leg line break at the reactor pressure vessel (RPV) is also considered. The RPV is covered with mirror RMI insulation and has a small amount of Tempmat fiber insulation around the incore instrumentation tubes on the bottom of the vessel. This break will affect the reactor insulation and the insulation on the RCS lines adjacent to the break, up to the penetrations. The Tempmat will be outside the ZOI. However, any debris will fall to the bottom of the reactor vessel cavity, which is a stagnant pool and will not transport to the ECCS Sump. The amount of debris generated by a break at this location is bounded by a hot or cold line break located elsewhere on the line. Therefore, a hot leg or cold leg break at the RPV was not analyzed further.

<u>EGC Response to Issue 3b3:</u>

EGC did not perform any destruction testing to determine ZOIs for Braidwood and Byron.

EGC Response to Issue 3b4:

Table 3b4-1
Summary of LOCA Generated Debris

Debris Type	**Units**	**Break S1**	**Break S2**	**Break S3 (Alternate)**	**Break S4**
INSULATION					
UNIT 1					
Mirror RMI	[ft^2]	85754	79638	40716	67541
Transco RMI	[ft^2]	0	0	0	0
Fiber (Transco Thermal-Wrap)	[ft^3]	0	0	0	0
UNIT 2					
Mirror RMI	[ft^2]	131464	138403	66235	126231
2.9D ZOI MIRROR INSULATION (Based on separate Cold Leg D break)					
Unit 1/2	[ft^2]	7239			
17D ZOI MIRROR INSULATION					
Unit 1	[ft^2]	62197	45379	N/A	64491
Unit 2	[ft^2]	89296	68860	N/A	99951
COATINGS (10D)					
Carboline – Surfacer 195	[ft^3]	15.051	15.051	5.433	15.051
Carboline - Carbozinc 11	[ft^3]	6.769	6.769	2.444	6.769
Carboline - Phenoline 305	[ft^3]	10.056	10.056	3.360	10.056
QUALIFIED COATINGS TOTAL (10D)	[ft^3]	**31.876**	**31.876**	**11.237**	**31.876**
COATINGS (5D for Epoxy, 10D for IOZ)					
Carboline – Surfacer 195	[ft^3]	1.548	1.548	0.559	1.548
Carboline - Carbozinc 11	[ft^3]	6.769	6.769	2.444	6.769
Carboline - Phenoline 305	[ft^3]	2.234	2.234	0.806	2.234
QUALIFIED COATINGS TOTAL	[ft^3]	**10.551**	**10.551**	**3.809**	**10.551**

Table 3b4-1
Summary of LOCA Generated Debris (continued)

Debris Type		**Units**	**Break S1**	**Break S2**	**Break S3**	**Break S4**
DAMAGED COATING		[ft^3]	0.417	0.417	0.417	0.417
UNQUALIFIED COATINGS						
Byron, Units 1 and 2 (See Note)		[ft^3]	12.20	12.20	12.20	12.20
Braidwood, Units 1 and 2 (See Note)		[ft^3]	12.20	12.20	12.20	12.20
LATENT DEBRIS						
Byron, Unit 1		[lbm]	67.28	67.28	67.28	67.28
Byron, Unit 2		[lbm]	124.63	124.63	124.63	124.63
Braidwood, Unit 1		[lbm]	126	126	126	126
Braidwood, Unit 2		[lbm]	72.83	72.83	72.83	72.83
BYRON, UNIT 1 FOREIGN MATERIAL						
Foreign Material		[ft^2]	546	546	546	546
Light Bulbs (only counted if in a ZOI)		[ft^2]	61	50	13	61
Adhesive		[ft^3]	0.12	0.12	0.12	0.12
BYRON, UNIT 2 FOREIGN MATERIAL						
Foreign Material		[ft^2]	694	694	694	694
Light Bulbs (only counted if in a ZOI)		[ft^2]	55	55	13	55
Adhesive		[ft^3]	0.01	0.01	0.01	0.01
BRAIDWOOD, UNIT 1 FOREIGN MATERIAL						
Foreign Material		[ft^2]	600	600	600	600
Light Bulbs (only counted if in a ZOI)		[ft^2]	84	69	18	84
Adhesive		[ft^3]	0	0	0	0
BRAIDWOOD, UNIT 2 FOREIGN MATERIAL						
Foreign Material		[ft^2]	457	457	457	457
Light Bulbs (only counted if in a ZOI)		[ft^2]	84	69	18	84
Adhesive		[ft^3]	0.0007	0.0007	0.0007	0.0007

Note: 12.20 ft^3 is a bounding unqualified coating value for all four units. Actual unqualified coating values are less than 12.20 ft^3.

It is recognized, however, that the 10D assumption does result in significant conservatism. Based on industry testing, epoxy coatings have been shown to withstand the effects of a pipe break at reduced ZOIs.

Therefore, for comparison purposes, one case has been performed with the approved guidance of 10D for all qualified coatings, and an additional case for qualified coatings has been performed with a 5D ZOI applied to epoxy coatings, and a 10D ZOI applied to inorganic zinc coatings. The results of these analyses show that the total coating debris generated with a reduced ZOI is about 1/3 of the coating debris generated with a ZOI of 10D (see Response to 3h5).

EGC Response to Issue 3b5:

The table below provides the total area of foreign materials and the amount of debris at the screen. The debris at the screen area represents reductions for the amounts transported to the ECCS Sump screen.

Table 3b5
Foreign Material Totals

Unit	Debris Type	Total Area [ft^2]	Debris at Screen [ft^2]
Byron 1	Junction Box Stickers	158.76	39.69
	Conduit Stickers	432.54	108.14
	Cable Tray Stickers	109.5	27.38
	Other Stickers/Tags/Tape/Labels/etc.	371.16	371.16
	Byron 1 Total		**546.37**
Byron 2	Junction Box Stickers	127.63	31.91
	Conduit Stickers	967.26	241.82
	Cable Tray Stickers	143	35.75
	Other Stickers/Tags/Tape/Labels/etc.	384.07	384.07
	Byron 2 Total		**693.55**
Braidwood 1	Junction Box Stickers	199.54	49.89
	Conduit Stickers	1080.88	270.22
	Cable Tray Stickers	91.15	22.79
	Other Stickers/Tags/Tape/Labels/etc.	257.15	257.15
	Braidwood 1 Total		**600.05**
Braidwood 2	Junction Box Stickers	171.57	42.89
	Conduit Stickers	207.48	51.87
	Cable Tray Stickers	99.5	24.88
	Other Stickers/Tags/Tape/Labels/etc.	337.81	337.81
	Braidwood 2 Total		**457.45**

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.*

EGC Response to Issue 3c1:

The debris sources at Braidwood and Byron Stations include insulation, coating, and latent debris. The insulation debris term is entirely RMI, stainless steel. The RMI includes Mirror Brand from Diamond Power (original plant installation) and Transco stainless steel RMI (installed during the Steam Generator Replacement Project). The characteristics of the insulation debris material are discussed in this section as the characteristics of the other debris types (i.e., coatings and latent) are included elsewhere.

The original debris term for Braidwood and Byron Stations included Thermal Wrap insulation installed on steam generators and connected piping. This insulation included a jacketed fiberglass core. Due to the high head losses associated with fiber, Braidwood and Byron Stations have replaced the thermal wrap insulation within its ZOI with Transco RMI. Although the Thermal Wrap is no longer part of the debris term, information is given below regarding the assumptions of the original debris generation analysis.

The GR and the SE do not list a destruction pressure for Transco Thermal Wrap insulation. Material properties and manufacturer published data indicate a similarity between Thermal Wrap and NUKON (both being low density fiberglass). Therefore, the destruction pressure of Thermal Wrap was taken as that of NUKON (i.e., 6 psi). This corresponds to a ZOI of 17D.

The ZOI for Transco RMI is given as 2.0 in the SE. Thus, the limiting quantity for RMI is Braidwood, Unit 2 and Byron, Unit 2 since these units only have Mirror RMI installed.

Mirror insulation is within a very large ZOI (28.6D), and therefore, will become debris even from a distant break. The quantity of Mirror RMI within both a 2.9D and 17D ZOI has also been calculated in order to support the determination of a conservative debris size distribution in the debris transport calculation. This computation is performed in addition to the determination of the quantity of Mirror RMI within a ZOI of 28.6D. The quantity of Mirror RMI within 2.9D and 17D ZOI is calculated in the same manner as the quantity within the 28.6D ZOI. However, the 2.9D ZOI Mirror RMI insulation debris is based on a more limiting break for that ZOI. After reviewing the insulation sources along the RCS main loop piping (which produces the largest ZOI), the break was chosen on the loop D cold leg between the RCP and stop valve. This break is the most limiting for a 2.9D ZOI due to insulation on the RCP, RCS lines, and various other smaller insulated lines that will fall within the 2.9D ZOI.

The Transco RMI foils are made of flat 2 mil thick stainless steel which has a density of 490 lbm/ft^3. The above densities are used to ensure that the proper materials are used in the bypass and head loss strainer tests.

RMI

Table 3c1 –1
Debris Quantities

Break S4	Mirror (ft^2)	Debris < 2" (Amount:Percent)	Debris ≥ 2 and ≤ 6 (Amount:Percent)	Debris> 6" (Amount:Percent)
Within 2.9D	7239	5067 ft^2 : 70%	2172 ft^2 : 30%	0 ft^2 : 0%
Between 2.9D and 17D	92712	2550 ft^2 : 2.75%	7417 ft^2 : 8.0%	82745 ft^2 : 89.25%
Between 17D and 28.6D	26280	131 ft^2 : 0.5%	657 ft^2 : 2.5%	25492 ft^2 : 97.0%
Totals:	126231	7748 ft^2 : 6.1%	10246 ft^2 : 8.1%	108237 ft^2 : 85.8%

Coatings

All failed qualified coatings within the ZOI and all unqualified coatings were characterized as fines.

Latent debris

All latent debris (fiber and particulates) was characterized as fines.

EGC Response to Issue 3c2:

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

It should be pointed out that the debris characteristics are not completely defined by density as the size of the debris dictates transportability as well. Additionally, the quantity of surrogate used for the phenoline material was seven times the actual predicted quantity. The debris sources developed from the debris generation analysis are divided into fines, small, large and intact large pieces, as applicable, and are consistent with the SE approved methodology and transport metrics for that type and size of debris based on NUREGs or NRC sponsored research.

Table 3c2 - 1
Debris Densities

Debris Source	Bulk Density	Material (or Surrogate) Density
INSULATION/FIBER		
RMI	N/A	490 lbs/ft^3
Latent Fiber	2.4 lbs/ft^3	175 lbs/ft^3
QUALIFIED COATINGS		
Steel		
Carbozinc 11	208	457 lbs/ft^3
Phenoline 305	101	167.4 lbs/ft^3
Concrete		
Surfacer 195	108	167.4 lbs/ft^3
Phenoline 305	101	167.4 lbs/ft^3
UNQUALIFIED COATINGS		
Carbozinc 11	208	457 lbs/ft^3

For the purpose of strainer design, the most important aspect of the latent debris characterization is the assumed fiber/particulate mix. However, the assumed mixture (15% fiber and 85% particulate) has minimal impact on the overall debris loading and performance of the new strainer. The bounding quantity of qualified coatings is 31.9 ft^3 and the bounding quantity of unqualified coatings is 12.2 ft^3. When considering a latent debris mass of 150 lbm, the total volume of latent particulate is less than 1 ft^3 regardless of the fiber particulate mixture. Thus, it can be seen the fiber/particulate mixture chosen has little impact (< 3% for baseline breaks) on the strainer particulate debris load. Therefore, for testing purposes, the particulate quantity was modeled with coating debris.

EGC Response to Issue 3c3:

The specific surface area (S_v) was only used for preliminary analytically determined head loss values across a debris laden ECCS Sump screen using the correlation given in NUREG/CR-6224, "Correlation and Deaeration Software Package." Since the head loss across the installed ECCS Sump screen is determined via testing, these values are not used in the design basis for Braidwood and Byron Stations. Therefore, these values are not provided as part of this response.

EGC Response to Issue 3c4:

The Braidwood and Byron debris generation, transport and head loss analyses have used the debris characterization assumptions provided in the SE. Specifically, the size of particulates is consistent with 10 micron for coatings particulate and the recommended size distribution for latent particulate.

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.*

EGC Response to Issue 3d1:

A latent debris walkdown was performed at Braidwood and Byron in accordance with the SE, Section 3.5. Using a masolin cloth, samples were collected from the various surfaces at different floor elevations and when practical, different locations on each floor. When a surface was not accessible for sampling, an alternate surface was selected and noted on the walkdown report, such as circular pipe for an inaccessible circular duct. The net weight differences between the pre-sample and post-sample weight were used to statistically extrapolate the amount of latent debris for the entire containment using a 90% confidence level.

Approximately 50 samples were taken and measured for each unit. Sampling criteria provided in the SE were employed, with a minimum of three samples taken for each surface type. To increase statistical accuracy, four samples were taken for each of the following types:

- Horizontal concrete floors
- Vertical concrete surfaces
- Grated surfaces at support beams
- Containment liner
- Cable trays (vertical)
- Cable Trays (horizontal)
- Horizontal equipment surfaces
- Vertical equipment surfaces
- Horizontal HVAC duct surfaces
- Vertical HVAC duct surfaces
- Horizontal piping surfaces
- Vertical piping surfaces

EGC 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. The latent debris walkdown procedure required the samples be weighed on a calibrated scale with an accuracy of at least +/- 0.01 grams.

The guidance provided in Section 3.5.2.3 of the GR indicates that latent debris characteristics could be determined using two methods:

1. Analyzing debris samples to determine composition and physical properties, or
2. Assuming debris composition and physical properties of the debris using conservative values.

The NRC found this guidance acceptable with respect to defining debris characteristics, provided that it was appropriately supplemented by the guidance given in the SE, Section 3.5.2.3. The latent debris characterization utilized in the Braidwood and Byron analysis follows Method 2 (i.e., assuming debris composition and physical properties). The assumed characterization of the latent debris for Braidwood and Byron, which is in accordance with the guidance provided in the SE, is as follows:

- Fiber contributes 15% of the mass of the total estimated latent debris inventory; particulate contributes the remaining 85%. As abnormal qualified coatings conditions do not indicate a dominant presence of paint chips in containment, this is considered acceptable.
- Latent fiber material has a mean density of 1.5 g/cm^3 (93.6 lbm/ft^3).
- Latent particulate material has a nominal density of 2.7 g/cm^3 (168.6 lbm/ft^3).
- Latent fiber material has an as-manufactured density (dry bed bulk density) of 2.4 lbm/ft^3.
- Latent fiber is assumed to have the head loss properties of commercial fiberglass. Since Transco Thermal Wrap fiber is still in containment (although outside the break ZOI), the Thermal Wrap fiber diameter (5.5 μm), reported in Table 3-2 of the GR, is used for latent fiber.

For the purpose of strainer design, a total latent debris quantity of 150 lbs is considered. The assumed fiber/particulate mix is 15% fiber and 85% particulate.

EGC Response to Issue 3d3:

Latent debris includes dirt, dust, lint, fibers, etc. that are present inside the Braidwood and Byron containments 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 NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," latent debris samples were collected to estimate the actual mass of latent debris inside of containment. The assumed 150 lbs quantity bounds the actual estimated latent debris quantities given below:

- The total amount of latent debris in Byron Unit 1 containment is 67.28 lbs.
- The total amount of latent debris in Byron Unit 2 containment is 124.63 lbs.
- The total amount of latent debris in Braidwood Unit 1 containment is 126 lbs.
- The total amount of latent debris in Braidwood Unit 2 containment is 72.83 lbs.

The bounding quantity of qualified coatings is 31.9 ft^3 and, depending on the station, the quantity of unqualified coatings ranges from 8.3 to 12.2 ft^3. Even when considering a latent debris mass of 150 lbm (to conservatively bound the measured quantities), the total volume of latent particulate is less than 1ft^3 regardless of fiber/particulate mixture; therefore, the fiber/particulate mixture chosen has little impact (< 3%) on the strainer particulate debris load.

The quantity of latent fiber has more of an impact on the strainer debris loading than latent particulate since latent fiber is the only source of fiber debris for Braidwood and Byron. Since the new Braidwood and Byron strainers have a filter area of approximately 3,000 ft^2, the minimum quantity of fiber required to form a 1/8" thin bed on the filter area is approximately 21 ft^3, which corresponds to a fiber mass of 50.4 lbm based on an as-manufactured density of 2.4 lbm/ft^3. This fiber mass (50.4 lbm) is more than 40% of the maximum measured latent debris mass and more than 30% of the assumed latent debris mass. Realizing that it is unlikely that the portion of latent fiber in containment is greater than 30% of the total latent debris load (especially considering how little fiber insulation is in containment), it can be concluded that the fiber/particulate mixture chosen has little impact on the strainer head loss.

EGC Response to Issue 3d4:

The amount of sacrificial area that has been allotted to foreign materials or miscellaneous latent debris is 900 ft^2.

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.*

EGC Response to Issue 3e1:

Guidance for the Braidwood and Byron debris transport methodology was provided by the GR and the SE for determining the debris transport fractions.

Debris transport is the estimation of the fraction of debris that is transported from debris sources to the ECCS Sump screen. In accordance with the guidance provided in Section 3.6.1 of the GR, four major debris transport modes were considered.

- Blowdown Transport – the horizontal and vertical transport of debris by the break jet
- Washdown (Containment Spray) Transport – the vertical transport of debris by the containment sprays/break flow
- Pool Fill-up Transport – the horizontal transport of the debris by break and containment spray flows to active and inactive areas of basement pool
- Recirculation Transport – the horizontal transport of the debris in the active portions of the basement pool by the recirculation flow through the ECCS/CSS system

The debris transport evaluation performed for Braidwood and Byron uses the guidance provided in the SE in addition to portions of the simple methodology presented in Section 3.6 of the GR. The blowdown and washdown transport analyses are performed consistent with Section 3.6 of the GR and Appendix VI of the SE. Pool fill-up transport analysis is performed consistent with Appendix III of the SE; however, no inactive volumes are modeled. An analytically refined recirculation transport analysis is performed using a computational fluid dynamics (CFD) model of the post-LOCA recirculation flow patterns in containment.

Guidance for the recirculation transport analysis is provided in Appendix III of the SE. The methodology in Appendices III and VI of the SE is for the NRC volunteer plant, which is a plant with a large, dry, cylindrical containment with a hemispherical dome and a 4-loop Westinghouse nuclear steam supply system (NSSS). Since Braidwood and Byron are also 4-loop Westinghouse NSSS plants with dry, ambient cylindrical containments, the overall methodology in Appendices III and VI of the SE is applicable.

Stainless Steel RMI Refinement

NUREG/CR-3616, "Transport and Screen Blockage Characteristics of Reflective Metallic Insulation Materials" (SAND83-7471), documents debris transport properties for stainless steel RMI. The following observations pertaining to RMI transport were made.

- Thick sheets of foil require higher velocities for transport than thin sheets (i.e. transport velocity tends to increase with material thickness)
- Crumpled foil tends to transport at lower velocities than uncrumpled foil
- Velocity of motion of samples (crumpled or uncrumpled foil) is much less than the flow velocity
- RMI transport modes include folding, tumbling, rolling, and sliding along the floor
- RMI does not become "waterborne" during transport; i.e., a portion of the foil is always in contact with the floor. Therefore the velocity contours at 1" above the floor are considered acceptable for RMI
- Walls tend to hinder transport
- Interaction of foil pieces with each other often causes jamming and immobilization of the pieces; high flow velocities are then required to break up jams and resume transport
- Because RMI does not become "waterborne" during transport (i.e., a portion of the foil is always in contact with the floor, it does not cause screen blockage to a height greater than the height and width of the debris (i.e., the RMI accumulates on the floor when it transports to a screen))

EGC Response to Issue 3e2:

There were no deviations from approved guidance regarding debris transport.

EGC Response to Issue 3e3:

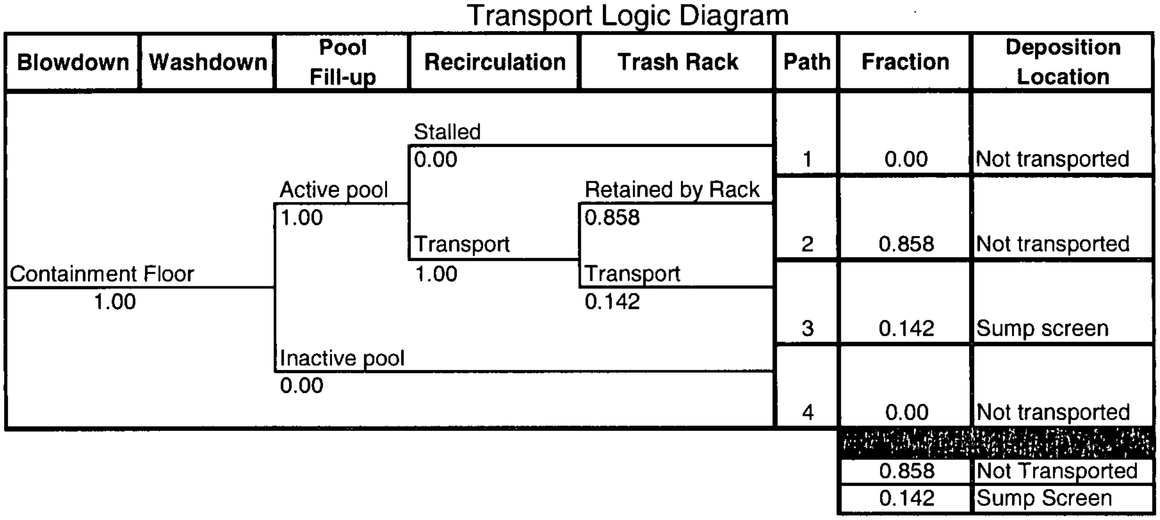
A three dimensional CFD model was developed to analyze the flow patterns toward the ECCS Sump during post-LOCA recirculation. This model was created using Fluent™ CFD software (Version 6.1.22). This program has been validated and verified under Sargent & Lundy's (contractor to EGC) Quality Assurance program.

Results from the CFD analysis of containment show high velocity (>0.40 ft/s) transport paths to the ECCS Sump pit area for all scenarios modeled. Therefore, all RMI debris can be transported to the vicinity of the ECCS Sump, regardless of whether 1 or 2 trains are operating. However, the trash rack debris retainer has been designed to prevent large RMI debris (debris too large to pass through a 4" by 4" opening) from being transported to the ECCS Sump.

Per NUREG/CR-3616, RMI debris transports by rolling, tumbling, and sliding and does not become "waterborne." Since the large RMI debris would have to become "waterborne" to transport over the trash rack's approximately fourteen inch long by approximately five inch high debris retainer, it will be retained and accumulate on the floor in front of the trash rack. With conservatively equating the RMI debris larger than six inches with the debris too large to pass through a 4" by 4" opening only the RMI debris less than 6" transports to the ECCS Sump screens. A debris pile may form in front of the trash rack debris retainer. Large RMI debris may be drawn through the trash rack openings by climbing over this pile. This mode of transport would be restricted by the interaction of the foil pieces which often causes jamming and immobilization, the height of the debris pile, and the presence of the horizontal debris retainer. The conservatism included in the calculation of the amount of small debris that is transported to the ECCS Sump screen bounds the minor fraction of the large debris that may transport past the trash rack by this path.

The figure below gives the Transport Logic Tree for RMI debris:

Figure 3e3-1
Transport Logic Diagram



RMI transport fractions that were determined using the logic trees are summarized in the table below:

Table 3e3 - 1
Debris Transport Fractions and Fractions of Debris Transported to the ECCS Sump Screen

	Size	Debris Transport Fraction		Fraction of Debris at ECCS Sump Screen	
Debris	Distribution	(Applicable to All Scenarios)		(Applicable to All Scenarios)	
Type	(Fraction)	Before CSS	After CSS	Before CSS	After CSS
Mirror RMI					
< 2"	0.061	1.00	1.00	0.061	0.061
>2", < 6"	0.081	1.00	1.00	0.081	0.081
> 6"	0.858	0.0	0.0	0.0	0.0
Sum	**1.0**	-	-	**0.142**	**0.142**

As shown above, 14.2% of Mirror RMI foil debris transports to the ECCS Sump screen for all scenarios.

Large RMI debris, relatively intact RMI, end covers, etc. due to RCS line breaks above the ECCS Sump do not transport to the ECCS Sump screen because the screen is sufficiently protected from blowdown debris by the top plate of the trash rack.

Since Braidwood and Byron each have a local (near potential breaks) ECCS Sump in containment, water will be drawn from both inside and outside of the secondary shield wall to the ECCS Sump screen. Debris may be transported along with the water. The quantity and types of debris that will reach the ECCS Sump screen are dependent on the flow velocities and flow patterns both inside and outside the secondary shield wall and the flow velocity at which debris transport occurs for each type of debris. In order to accurately model the flow velocities to the ECCS Sump screen, a CFD analysis was utilized.

The CFD model geometry includes the following salient features:

- containment modeled from nominal elevation 377' 0" (containment floor) to elevations 378.458' (17.5" water level) and 379.125' (25.5" water level)
- major obstructions such as the steam generator pedestals and supports, reactor coolant pump supports, pressurizer supports, stairs, pressurizer relief tank, reactor coolant drain tank room, permanent storage area, and reactor containment fan cooler (RCFC) rooms
- detailed model of the existing inner and outer ECCS Sump screen mesh and grating
- break flow modeled with both vertical and horizontal velocity components
- detailed model of CSS and the In Core Instrumentation (ICI) tunnel flow into ECCS Sump pool

EGC Response to Issue 3e4:

The containment recirculation sumps are located within the missile shield wall; the post-LOCA water volume that leaks out from the RCS has a direct path to the sumps. This design does not provide the opportunity to use a debris interceptor design within the flow path to the sumps. Debris retainers, approximately fourteen inches long by five inches high are used at the trash rack to prevent large RMI debris from reaching the screens.

EGC Response to Issue 3e5:

Braidwood and Byron did not credit the settling of debris fines.

EGC Response to Issue 3e6:

Summary of Debris Transport Calculations

Table 3e6 - 1
Summary of Debris Transport Modes

Transport Mode	Details
Blowdown	All particulate and RMI debris is transported to the containment floor. No debris is transported upwards to the containment dome. For breaks located directly above the ECCS Sump, all debris is conservatively transported to the ECCS Sump.
Washdown	Since all particulate and RMI debris is modeled as transporting to the containment floor during blowdown, there is no washdown transport.
Pool Fill-up	All particulate and RMI debris is transported toward the ECCS Sump pits. No transport to inactive volumes is modeled.
Recirculation	The velocity contours provided in the CFD analysis are used to determine whether each debris type will stall or transport towards the ECCS Sump. All RMI debris in the active pool can be transported to the vicinity of the ECCS Sump. However, all RMI debris greater than 6" will be retained by the trash rack.

Table 3e6 - 2
Bounding Debris Quantity at ECCS Sump Screen for Braidwood and Byron

Debris Type	Units	Fraction of Generated Debris at ECCS Sump Screen	Debris Quantity at ECCS Sump Screen
SS Mirror RMI Foil[4]	[ft^2]	0.142	21,593[5]
Qualified Coatings 10D (epoxy/epoxy phenolic)[3]	[ft^3]	1.00	25.107
Qualified Coatings 10D (inorganic zinc)	[ft^3]	1.00	6.769
Damaged Coatings	[ft^3]	1.00	0.417
Unqualified Coatings	[ft^3]	1.00	12.20
Foreign Materials	[ft^2]	1.00	694
Light bulb glass[1]	[ft^2]	1.00	84
Adhesive	[ft^3]	1.00	0.12
Latent Debris[2]	[lbm]	1.00	150

1. Bounding light bulb glass area for all 4 units is for Braidwood, Units 1 and 2.
2. The recommended latent debris total is 150 lbm.
3. The quantity of qualified coatings (epoxy/epoxy phenolic) at the ECCS Sump screen when considering a 5D ZOI is 3.782 ft^3.
4. Only the Mirror RMI less than 6" in size transports to the ECCS Sump screen. Mirror RMI debris larger than 6" is retained at the trash rack.
5. Quantity conservatively increased by approximately 20%.

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.*

EGC Response to Issue 3f1:

Diagrams of the Braidwood and Byron ECCS and CSS are provided in Attachment 2 to the submittal.

EGC Response to Issue 3f2:

The containment ECCS Sump screens are entirely located within the ECCS Sump pits below the containment floor elevation of 377 ft. There are three large openings in the concrete floor into each ECCS Sump that allow water to flow into the ECCS Sump.

Calculations for minimum containment flood level have demonstrated that, for a Small Break LOCA and a Large Break LOCA, the ECCS Sump screens will be submerged at the time of ECCS switchover to the containment ECCS Sump. The minimum calculated flood level, above elevation 377 ft, is as follows:

- SBLOCA – 4.8"
- LBLOCA – 9.2"

The top of the screens is located in excess of 24" below elevation 377 ft; thus the minimum design submergence for the screens is as follows:

- SBLOCA – 28.8"
- LBLOCA – 33.2"

The minimum flood levels given above are at the time the suction of the RH pumps are switched over to the containment recirculation sumps. One RH pump takes suction from each ECCS Sump. Thus, the ECCS Sump flow rate is about 50% of the design flow rate, which includes flow from one CSS pump. At the time the CSS pumps' suctions are switched over to the containment recirculation sumps, the containment flood level is as follows:

- SBLOCA – 21.2"
- LBLOCA – 25.6"

Thus, the screens' submergence at the time of maximum flow rate from the ECCS Sump is:

- SBLOCA – 45.2"
- LBLOCA – 49.6"

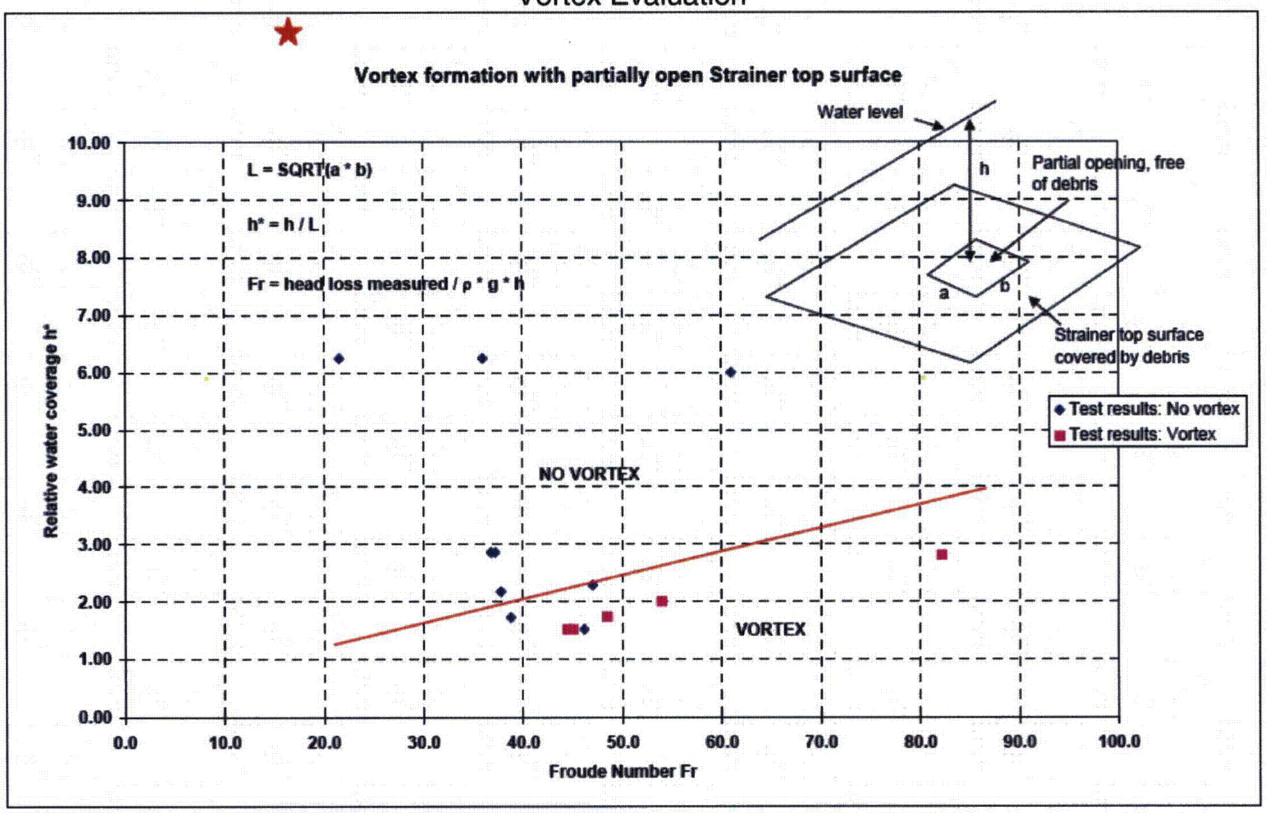
EGC Response to Issue 3f3:

Based on testing and evaluations, the strainers at Braidwood and Byron will not experience vortexing. The most bounding condition with respect to vortex formation occurs when flow through the strainer is temporarily stopped. When this occurs, it is possible that air which evolves downstream of the debris bed on the strainer will rise, thus causing small openings in the debris bed. When flow through the strainer is reinstated, it is then possible that very high velocities will be experienced through the small openings which were formed when the flow was stopped. These velocities could cause vortices to form. To address this phenomenon, CCI performed a series of tests.

The test series which CCI performed consisted of a parametric evaluation in which various combinations of flow rate and submergence were tested to determine when vortices would form when the top surface of a strainer was partially open. The flow rate was non-dimensionalized using the Froude number (Fr) and the submergence was non-dimensionalized by computing the ratio (h*) of the submergence to the characteristic size of the opening at the top of the strainer such that the test results could be applied to a range of conditions. The results of this testing are provided in Figure 3f1 below.

The vortexing evaluation for Braidwood and Byron is based on the physical design and installation of the strainer, as well as, on CCI testing. The Braidwood and Byron strainers are located entirely within the ECCS Sump pits below containment elevation 377 ft. (the containment basement). The minimum submergence of the strainers, given that they are located entirely within the ECCS Sump pits beneath the floor, is in excess of 24" as stated in the Response to Item 3f2.

Figure 3f3-1
Vortex Evaluation



For Braidwood and Byron, the Froude number based on the maximum allowable head loss (the structural design limit of 4.736 m or 6.7 psi) is 15.5. Similarly, the non-dimensionalized submergence, h*, is 12.3 based on an assumed characteristic hole size of 0.05 m (2"). This characteristic size is considered reasonable for an opening in the debris bed caused by an air bubble rising to the surface. These two values are shown in the figure above by the star (★). As can be seen, this condition is clearly in the range of parameters for which vortexing will not occur due to an opening in the debris bed on the top of the strainer.

For strainer operation during which pump flow is uninterrupted (normal condition), the velocity around the strainer will be approximately uniform (i.e., no areas of extremely high velocity) for both clean and debris laden conditions. For the maximum strainer flow rate of 10,000 gpm, the approach velocity upstream of the strainer pockets is 0.045 m/s (0.15 ft/s). In addition, the "holes" in the strainer for normal operation would either be the strainer hole size (1/12" per the Response to Issue 3j) for the clean screen condition or the size of an interstitial hole in the debris bed for the debris laden condition. Applying these small hole sizes to the h* parameter discussed above results in an extremely large h* value, for which vortex formation will clearly not occur. Thus, based on the strainer submergence, the expected strainer approach velocities, and the CCI testing, no vortices will form during normal strainer operation.

EGC Response to Issue 3f4:

EGC used the ECCS Sump screen supplier, CCI, to perform plant specific strainer head loss testing.

Three different test loop configurations were utilized for the EGC testing program for Braidwood and Byron head loss testing, as follows:

1. Small Scale Vertical Loop at CCI's facility in Winterthur, Switzerland;
2. Large Scale Tank Testing in Winterthur, Switzerland (utilized a two sided strainer array and horizontal flow into the strainer);
3. Multi Functional Test Loop (MFTL) at CCI's facility in Winterthur, Switzerland (utilized one sided strainer array and horizontal flow).

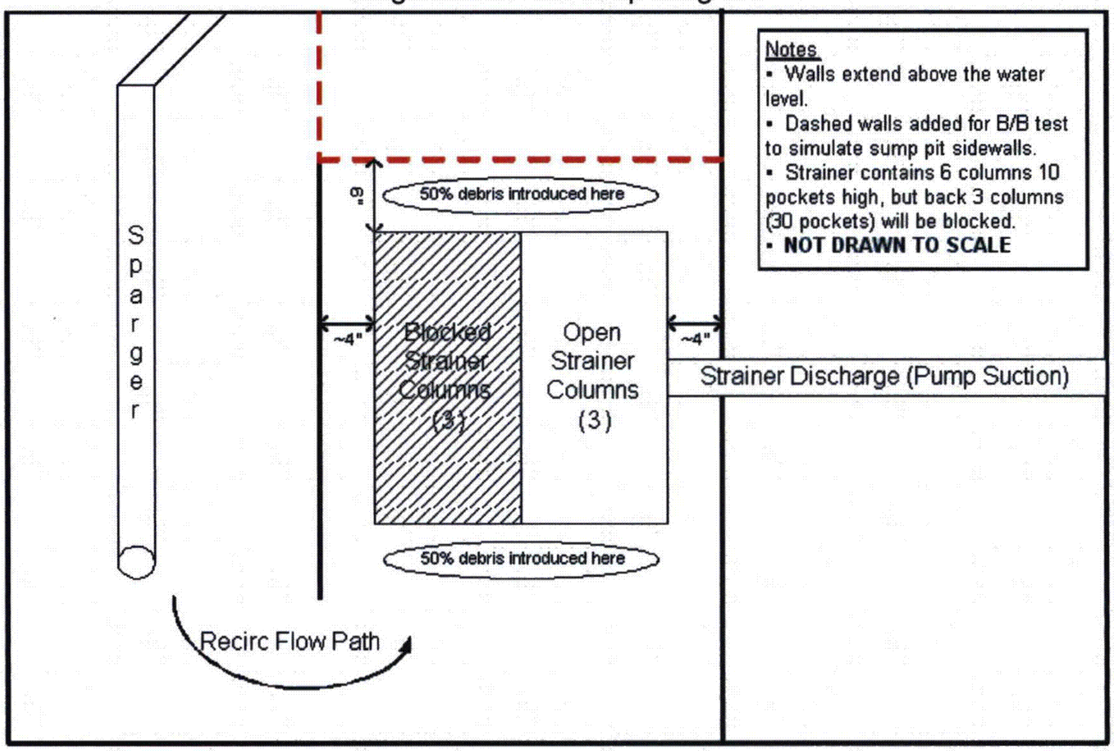
Small Scale Testing Loop:

The Small Scale testing loop was used mainly for informational purposes and to gain an initial understanding of head loss behavior from various types of debris combinations. The results of this portion of the test program were not used as input into the head loss calculations for the new strainers.

Large Scale Testing Loop:

The Large Scale testing loop contained a two-sided strainer array with three CCI strainer cartridges, per side, with 60 pockets placed in a pool that is filled with water. Walls were erected in the test tank, around the strainer module, to simulate the Braidwood and Byron ECCS Sump pit configuration (see sketch below showing a plan view of the test tank).

Figure 3f4 – 1
Large Scale Test Loop Diagram



This testing provided input into design decisions on removal of fibrous insulation within the ZOI and further information into the expected head loss behavior of various types of debris. The results of this portion of the test program were used to understand the influence on head loss between modeling coating debris as particulate versus paint chips. The paint chips used in the testing were made from coating materials that are representative of the types used in the plants and were broken down such that the majority of the chips were smaller than 1/4" in size. Inorganic zinc (IOZ) based coatings were modeled using IOZ powder in the prescribed quantities for both tests.

The reason for these tests was the relatively small amount of fibers available, which produces the following theoretical debris layer thickness:

Thickness = Volume of fibers / filtering surface = 9.375 ft^3 / 2120 ft^2 = 0.0044 ft.

A typical minimum "thin bed" thickness is, according to the GR, approximately 1/8" or 0.0104 ft, which means that the available fiber can only form about 40% of a classical minimum thin bed thickness. CCI's reported experience has been that paint chips have not generated a substantial head loss in cases with small fiber loading. The head losses measured from the 100% flow rate cases of these tests, were as follows:

- test #4 with coating particles : 12.3 mbar
- test #7 with coating paint chips : 0.563 mbar.

This comparison demonstrates that the assumption of the coatings being decomposed into fine particles (versus paint chips) is conservative. Therefore, the use of particles in all follow-on testing was prescribed.

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 is realized 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 means of the frequency controlling of the rpm of the pump motor. 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.

For each test group, the CCI strainer segment with 40 representative pockets is placed in the Plexiglas channel before the loop is filled with water. In order to simulate the plant ECCS Sump pit configuration at Braidwood and Byron, the testing loop used a solid plate placed approximately 260 mm (~10") away from the strainer to keep the RMI close to the strainer surface and to create a vertical flow field through the RMI.

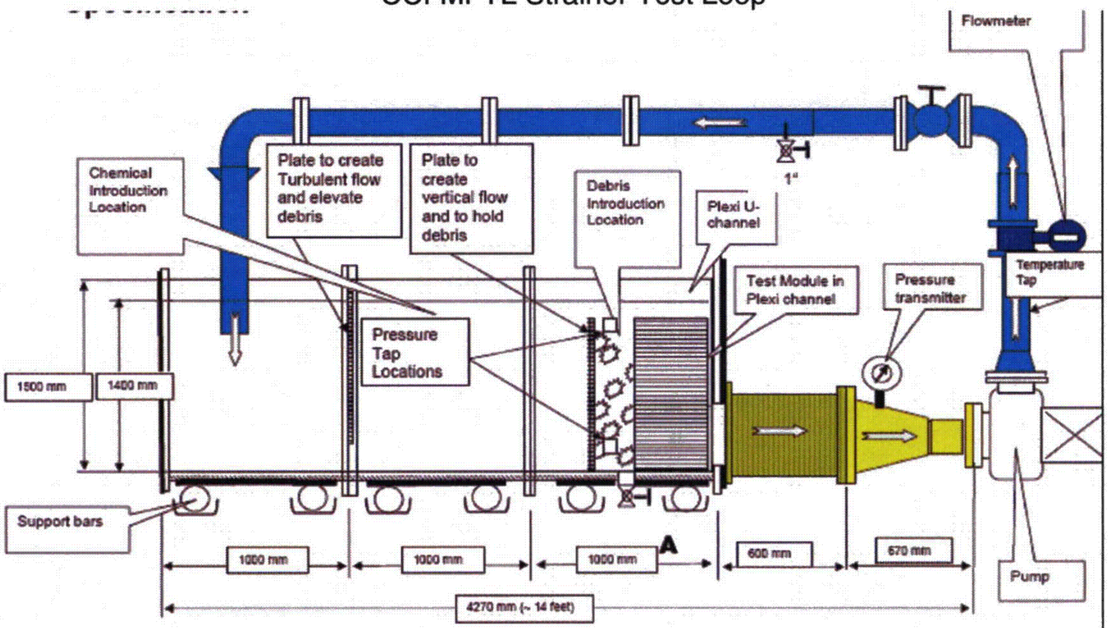
The plate height was approximately 2' 3" above the strainer pockets, but was adjusted as needed to ensure a minimum submergence of 1". The head loss across the strainer was measured by means of calibrated differential pressure transducers with a range of 0 - 1 bar. The pressure taps in the system are directly downstream of the plate at both the bottom and top of the loop. The approximate locations can be seen in Figure 3f4 - 2. Continuous head loss measurements were taken throughout each test.

An additional solid guiding plate was added in the loop near the discharge pipe as shown in Figure 3f4 - 2. This plate creates turbulence flow that keeps the debris from settling between the two walls. The height off of the floor was adjusted in order to ensure minimal settling occurs.

In the actual Braidwood and Byron installation, one side of the strainer banks has a wall an average of approximately 5 1/8" away from the strainer surfaces and the other side of the strainer banks are relatively open. Modeling both of these flow conditions simultaneously in the MFTL is not practical. However, flow approaches the strainers in the ECCS Sump pit from the vertical direction and this was modeled. Also, the flow into the pockets, in the installed configuration, is horizontal at the face of the pockets for both the pockets in the interior and the pockets facing the wall and this condition was modeled. A CFD analysis was performed based on the ECCS Sump configuration and the inputs from this testing were used as part of the input for final head loss calculation CFD analysis.

The test specimen was 4 pockets wide by 10 pockets tall. The submergence of this test specimen is much less than the submergence of the actual installation. The submergence of the actual installation cannot be modeled due to the limitations of the loop height.

Figure 3f4 - 2
CCI MFTL Strainer Test Loop



The test program did not take credit for near field debris settling. The debris was introduced directly at the inlet surface of the strainer (location shown in Figure 3f4 - 2). The chemicals were introduced in the middle section of the loop upstream of the wall holding the RMI. The volume of water in the test loop is approximately 1700 Liters.

Very little debris settlement occurred in the MFTL testing. For the Braidwood and Byron testing a solid guiding plate was added in the loop near the discharge pipe. This plate created turbulence flow that kept the debris from settling during loop operation. The height of this wall off of the floor was adjusted in order to ensure minimal settling occurred. Through the use of turbulent flow and vertical flow field near the surface of the strainer, much of the debris remained elevated during the entire loop operation and never settled on the strainer or floor (until flow in the test loop was shutdown).

Test scaling methodology:

The basis for ECCS Sump screen area for the testing was a filtering surface of 3020 ft^2, (actual calculated area of final design in the head loss calculation is 3031 ft^2). A total of 900 ft^2 is the sacrificial surface area for labels and placards based on plant walkdown information. The equivalent active filtering area for testing therefore was 2120 ft^2 (3020 ft^2 – 900 ft^2). Debris quantities and flow rate for this surface was scaled for testing at the 100% debris quantities. This resulted in a scaling ratio of 39.4 for the MFTL facility.

Flow scaling is summarized in Figure 3f4 - 3 and Table 3f4 – 1 below. MFTL test scaling factor is also used for test flow rate scaling.

Figure 3f4 – 3 and Table 3f4 – 1

The basic dimensions of a pocket are shown here:

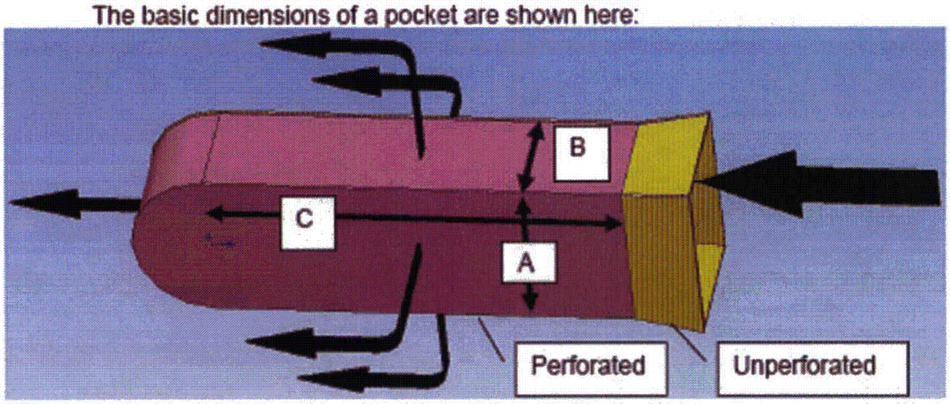


Figure 3: CCI Strainer Pocket

The following table shows the calculation of the filtering surfaces in reality and the filtering surface of the test specimen with 40 pockets.

INPUTS	PROPOSED POCKETS		TEST POCKETS	
Units	mm	inch	mm	inch
A	109	4.29	109	4.29
B	70	2.76	70	2.76
C	328	12.91	288	11.34
Radius= A/2	54.5	2.15	54.5	2.15
Total Perforated Pocket Area	138740.49	215.00	124420.49	192.85

	m^2	ft^2	m^2	ft^2
Total Area	280.57	3020.00	5.00	53.82
Reduction (Tapes, Tags & Stickers)	83.6	900.00	0	0.00
Effective Resultant Area	196.97	2120.00	5.00	53.82

Overall Test Scaling Factor	39.394

Following is the basis quantities of debris that were used for MFTL testing debris quantity scaling:

These mixtures can be lumped into five relevant categories:

- RMI
- fibers
- particulates (qualified coatings, epoxy, latent particulates, and adhesive)
- IOZ and unqualified coatings
- light bulb glass

The tapes, tags, and stickers have been considered in the overall test scaling factor by reducing the real surface conservatively by the whole 900 ft^2. Therefore, these debris constituents need not be tested.

Two non-chemical tests (Test 1, Table 3f4 – 2, and Test 2, Table 3f4 - 3) were performed prior to performing the chemical tests. The unqualified coatings amount were modeled by IOZ and zinc dust in Test 1 and modeled by epoxy/stone flour in Test 2. The debris make-up that yielded the highest head loss was used for all the follow-on chemical tests.

Table 3f4 – 2
Test 1 Debris Composition

Design	100% Test Quantity scaled by test scaling factor		Source
126,231 ft^2	Based on filling volume in front of test specimen to bottom of top row of pockets		RMI (Reflective Metal Insulation)
9.375 ft^3	0.24 ft^3	0.0068 m^3	Uncompressed Fibrous insulation (latent fiber only)
26.96 ft^3 4513 lbm(1)	114.5 lbm	51.9 kg	Latent particulate, Qualified epoxy coating, Adhesive
12.8 ft^3 5850 lb(2)	148.5 lbm	67.36 kg	Unqualified Coatings
7.1 ft^3 3245 lbm(2)	82.4 lbm	37.37 kg	Qualified IOZ Coatings
88.7 ft^2	2.25 ft^2	0.21 m^2	Glass

(1) Based on a surrogate material density value of 167.4 lbm/ft^3.
(2) Based on an IOZ with a particle density of 457 lbm/ft^3 and using zinc dust in the testing.
Note: Zinc dust obtained from Carboline paint company to represent the IOZ coating in the plant; typically Carbozinc 11 coating.

Table 3f4 – 3
Test 2 Debris Composition

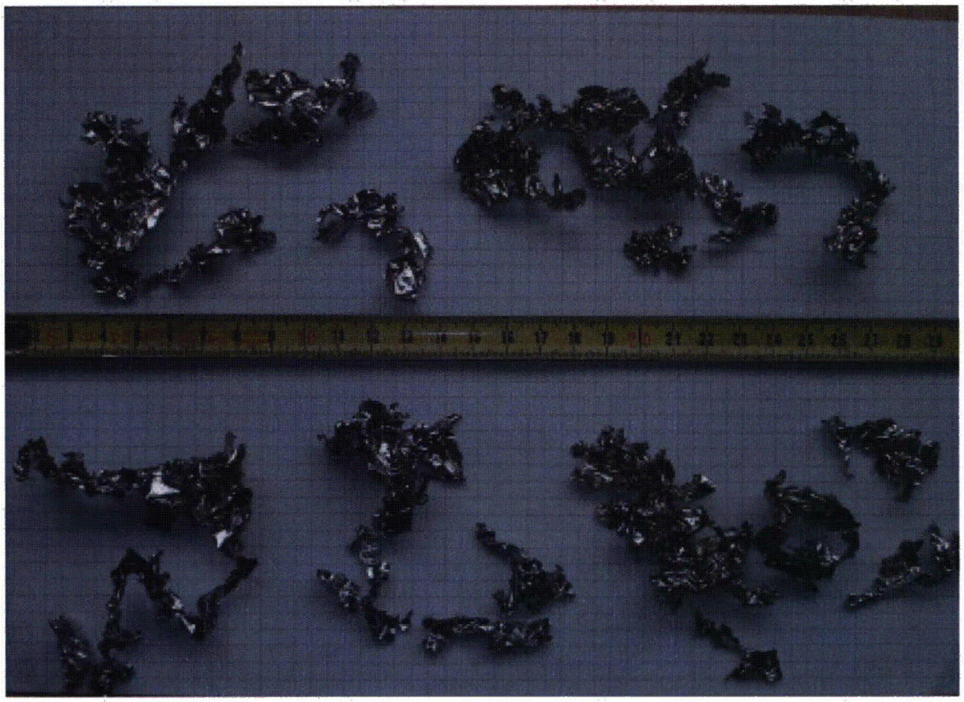
Design	100% Test Quantity scaled by test scaling factor		Source
126,231 ft^2	Based on filling volume in front of test specimen to bottom of top row of pockets		RMI (Reflective Metal Insulation)
9.375 ft^3	0.24 ft^3	0.0068 m^3	Uncompressed Fibrous insulation (latent fiber only)
26.96 ft^3 4513 $lbm^{(1)}$	114.5 lbm	51.9 kg	Latent particulate, Qualified epoxy coating, Adhesive
12.8 ft^3 2143 $lbm^{(1)}$	54.4 lbm	24.7 kg	Unqualified Coatings
7.1 ft^3 3245 $lbm^{(2)}$	82.4 lbm	37.37 kg	Qualified IOZ Coatings
88.7 ft^2	2.25 ft^2	0.21 m^2	Glass

(1) Based on a surrogate material density value of 167.4 lbm/ft^3.
(2) Based on an IOZ with a particle density of 457 lbm/ft^3 and using zinc dust in the testing.

RMI in the test was composed of pre-shredded stainless steel foils with a thickness of 0.05 mm (0.002"). The foils were prepared by a commercial shredding company, which tore and crumpled the RMI foils using a mechanical process to approximate the size distribution given in Appendix VI, p. VI-16 of the SE. A representative sample of the shredded RMI is shown in the following picture. The unit of measure of the ruler is centimeters.

RMI in the test is composed of pre-shredded stainless steel foils with a thickness of 0.05 mm (0.002") will be used. The foils were prepared by a commercial shredding company which tore and crumpled the RMI foils using a mechanical process to approximate the size distribution given in Appendix VI, p. VI-16 of the SE. A representative sample of the shredded RMI is shown in the following picture. The unit of measure of the ruler is centimeters.

Photo 3f4-1
RMI Size Distribution



As will be discussed in the results section, the RMI addition was shown to actually reduce head loss. This is attributed to disruption of the former debris bed by RMI partially being sucked into the pockets and "scratching" the debris bed open. Consequently, for conservatism RMI was not added to the test loop debris mixture in subsequent chemical testing.

The fibers used in the test had an as-fabricated density of 2.4 lb/ft^3, consistent with the SE Section 3.5.2.3. The fibers were decomposed by first cutting with a leaf shredder, manually tearing the shredded fibers into smaller pieces and then soaking the pieces in a water bucket. A water jet was used to separate the fiber in the bucket after being shredded by the leaf shredder. The fibers used in the testing were produced by Transco.

<u>Particulates Represented by Stone Flour:</u>

Epoxy coating particulates are characterized by a sphere diameter of 10 µm. Since this is a theoretical value and real available particulates always have a size distribution spectrum, CCI choose to use a surrogate particulate product with a similar S_v value as a theoretical product with only spheres of 10 µm.

The S_v value of spheres at 10 µm is equal to 6/1.E-5 (600,000 m-1 or 0.6 m^2/cm^3). CCI used a stone flour product available from COOP (a Swiss corporation) for strainer performance testing which comes very close to this value. The size spectrum analysis was performed by CCI and its S_v value is 0.776 m^2/cm^3, corresponding to a sphere diameter of 7.7 µm. This was a recently measured value at the time of the testing, which is bounded by the 10 µm.

The quantity of particulates at the strainer is defined by volume. However, the particulate quantity for the tests is measured by weight. Therefore, the volume quantity is converted to weight using the density of the surrogate particulates. The surrogate particle material density was measured to be: 2680 kg/m^3 or 167.4 lbm/ft^3.

The particulates are mixed together with the fibers (and RMI where appropriate) in the water bucket after decomposition of the fibers. Particulates do not need decomposition, since they already come in a form of flour and distribute instantly. The flow field in the Braidwood and Byron ECCS Sump is vertical, but turns horizontal at the surface of the strainer. The vertical flow field was modeled in the test loop as much as practical. Due to this flow field and the introduction of debris at the surface of the strainer, the effects of settlement of stone flour when compared to the settlement of epoxy coating is minimized.

Inorganic Zinc Particulates:

For testing IOZ (both qualified and unqualified), zinc filler for IOZ coatings was ordered from Carboline per EGC specifications. The mass of the zinc dust needed for the testing was calculated using the volume of IOZ coating and a particulate density of 457 lbm/ft^3. The particulates are characterized by a sphere diameter of 10 µm (e.g., the GR, Table 3-3, coating debris characteristics). Since this is a theoretical value and real available particulates always have a size distribution spectrum, CCI choose to use a surrogate particulate product for IOZ with the same S_v value as a theoretical product with only spheres of 10 µm. The S_v value of spheres at 10 µm is equal to 6/1.E-5 (600,000 m-1 or 0.6 m^2/cm^3). The S_v value is 0.573 m^2/cm^3, which corresponds to a sphere diameter of 10.5 µm. This was a measured value at the time of the testing, which is near 10µm.

Glass Particulate:

Glass from a fluorescent tube was used to simulate the light bulb particulates due to the simplicity of calculating the surface area of a cylindrical tube. The area of glass defined was then determined by weight and documented. The glass particulate was crushed such that pieces approximately 1/2" or smaller were created.

MFTL Test Results:

The test results of the MFTL tests are summarized in the following. The head loss values are also normalized by the ratio of the pure water viscosities to 20°C, which allows direct comparison of the values. The justification for the linearity between head loss and viscosity is given by the equation B-21 of NUREG/CR-6224.

Since the term with the square of the velocity becomes negligible at the velocities applicable here, the head loss is proportional to viscosity and velocity. Moreover, for the sub-thin-fiber-beds considered, the compressibility (equations B-24 and B-25 of NUREG/CR-6224) does not play a role and the density is very nearly constant. Therefore, the head losses can be converted to other temperatures on the basis of the proportionality to viscosity.

Table 3f4 – 4
Test #1 (with Zinc as unqualified coating, w/o chemicals)

Case	Temperature (°C)	Head Loss (mbar)	Head Loss normalized to 20°C(mbar)
100% Debris before RMI addition	19.3	69.4	68.1
100% Debris after RMI addition	20.1	56.3	56.4

Table 3f4-5
Test #2 (with Stone flour as unqualified coating, w/o chemicals)

Case	Temperature (°C)	Head Loss (mbar)	Head Loss normalized to 20°C(mbar)
100% Debris before RMI addition	19.0	47.6	46.4
100% Debris after RMI addition	19.8	47.9	47.6

These results show the following:

Test #1, with unqualified coatings modeled as Zinc filler, shows higher head losses than Test #2 with unqualified coatings modeled as stone flour and is therefore used further. (Test #2 is not used further). The RMI addition actually reduces head loss. This is attributed to disruption of the former debris bed by RMI partially being sucked into the pockets and "scratching" the debris bed open. The way of addition of RMI obviously has some variability. This is reflected in the fact that there was a slight reduction of head loss in test 1 and almost no net effect in Test #2. The conclusion remains the same that the additional head loss due to RMI addition can be neglected for the two tests.

Test termination criteria

The available head loss that can be devoted to the strainer and debris bed is 5 ft. This head loss will be consumed through three main regions:

1. The head loss through the RMI/debris bed outside of the pockets
2. The head loss through the pockets
3. The clean strainer head loss

A CFD analysis has been performed on these regions as discussed in the Response to Issue 3f5.

This testing was used as input into the CFD and as a means to verify the CFD applicability to the head loss that is seen in the plant installation. The CFD analysis shows that a total of approximately 3 ft of head loss will be consumed by the clean strainer leaving 2 ft of allowable head loss through regions 1 and 2 mentioned above. Therefore, the stabilization criteria shown in Table 3f4-7 were created based on the total head loss allowable of 2 ft.

Table 3f4-6
Test Termination Criteria

Head Loss Amount in Test	0 ft – 0.5 ft 0 cm – 15.24 cm	0.5 ft – 1 ft 15.24 cm – 30.48 cm	1 ft or Greater 30.48 cm or Greater
Stabilization Criteria for Consecutive Chemical or Debris Additions	3% in 10 minutes	3% in 20 minutes	1% in 30 minutes
Termination Criteria	The final value taken in all tests must meet the 1% in 30 minutes stabilization value for two consecutive 30 minute periods regardless of the head loss range.		

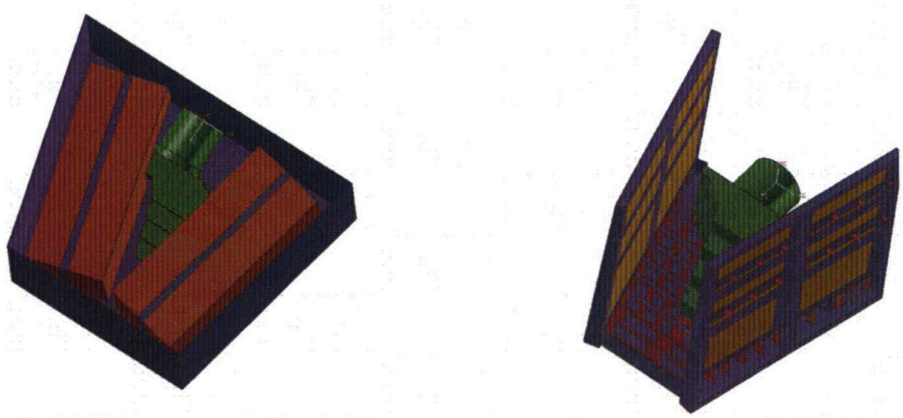
Information on how chemical effects was accounted for in the testing is provided in EGC Response to issue 3o of this transmittal; the industry guidance provided in WCAP-16530-NP, "Evaluation of Post Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," was used for generation of precipitants.

<u>EGC Response to Issue 3f5:</u>

The Braidwood and Byron design includes two separate containment recirculation sumps, fully redundant, each servicing one train of the ECCS. Replacement screens have been installed in each ECCS Sump. To satisfy single failure criteria (one ECCS train does not start), each ECCS Sump's screens have been sized to accommodate the maximum volume of debris that is predicted to arrive at the ECCS Sump screen. Therefore, when both ECCS trains operate as designed, each will, in theory, be required to accommodate 50% of the screens' design basis debris load.

The ECCS Sump was modeled using the ANSYS CFX10 CFD software. The program was validated according to CCI's Quality Assurance Program. The model consists of a 3D Parasolid model provided by CCI AG which was imported to the CAD-tool Unigraphics and adapted to guarantee an accurate geometric simulation. The flow domain comprises the whole ECCS Sump geometry, consisting of the strainer structure, filter pockets, and cavities up to the suction pipe. The CAD and CFD models represent all four Braidwood and Byron units. Figure 3f5-1 shows an overview of the complete simulation domain. The left image shows the domain without the RMI filling. The right shows the spaces located inside the strainer structures. The pockets of the filter have been modeled by a porous material spread out over the total volume of the pockets, having laminar flow resistance in the pocket depth direction and infinite resistance in other directions. The RMI bed filling height determined from the RMI fine quantity and a K_t (inner foil gap thickness) value of 0.012 ft is 1.52 ft below the filter module height. This means that approximately two rows of filter pockets are free of RMI.

Figure 3f5-1
CAD Model of the ECCS Sump Strainer



EGC Response to Issue 3f6:

Braidwood and Byron are RMI plants. The only fiber debris term is due to the assumed latent debris characteristics. The new strainer in each ECCS Sump has a filter area of more than 2,000 ft^2; therefore, the minimum quantity of fiber required to form a 1/8" thin bed on the filter is approximately 21 ft^3 [(1/8") / (12 in/ft) * (2,000 ft^2)], which corresponds to a fiber mass of 50.4 lbm [(21 ft^3)*(2.4 lbm/ft^3)] based on an as-manufactured density of 2.4 lbm/ft^3. Less fiber than this would not be able to form a uniform debris bed capable of developing significant head losses. The design basis debris mass for Braidwood and Byron Stations is 22.5 lbs. This amount of latent fiber would form a uniform bed of 0.05625" in thickness; thus, a thin bed will not form on the screens. If both trains operate, the amount of latent fiber would form a uniform bed of only 0.028" in thickness.

EGC Response to Issue 3f7:

The strainer design maximum head loss is five (5) ft at a total ECCS Sump flow rate of 10,000 gpm. The ECCS Sump flow rate for each ECCS Sump includes flow from one RH pump and one CSS pump. The total ECCS Sump flow of 10,000 gpm that has been used for the head loss testing is larger than the maximum calculated combined flow rates (appoximately 9,000 gpm).

The strainer postulated maximum head loss of 4.2 ft, at 200°F, is due to the maximum quantity of debris that was calculated to reach the screens, including chemical effects. The total head loss (at 200°F) upstream of the ECCS Sump suction pipe includes the head loss contribution from:

Table 3f7-1
Strainer Head Loss

	Head Loss (ft)
RMI in the ECCS Sump Pit	0.196
Debris in the Filter Pockets	0.86
Flow in Screen internal cavities (waterbox) including suction pipe entrance loss	3.15

The head loss due to debris in the filter pockets also includes the contribution of chemical effects. The testing uses maximum ECCS Sump flow rates (due to RH and CSS pumps) and the chemical quantities that are calculated to be present in containment at 30-days following the event. Considering that the emergency procedure include steps to shutoff the CSS pumps at eight (8) hours after the event, the 30-day chemical quantity will be at the screen when the flow through the screen is about 50% of the design basis flow rate, thus resulting in lower head loss.

An additional conservatism of 0.93 ft is included in the CCI screen head loss. Normally, the head losses of strainers including their internal cavities are presented on the basis of total pressures (i.e., pressures that are a sum of the static pressures and the dynamic head). However, CCI used static pressures, which leads to a calculated conservatism of 0.93'. Therefore, all total head loss given for the screen assembly can be considered conservatively high by 0.93'.

The margin to the maximum head loss is thus 1.73 ft (5 ft – 4.2 ft + 0.93 ft).

Additional testing was done for 120% and 140% chemical debris. The total head loss increased to 4.35 ft (120% case) and 4.39 ft (140% case) at 200°F. This head loss increase is minimal and can be absorbed by the margin discussed above.

EGC Response to Issue 3f8:

The Braidwood and Byron ECCS Sump strainer design incorporates the following conservatisms in the head loss and vortexing evaluations which results in additional margin.

- Each screen is sized for the 100% quantity of debris that is predicted to transported to the ECCS sump. Each unit has two sumps – the screen for each ECCS Sump has been sized to handle the entire debris load for the unit.
- The head loss testing was done at a flow rate of 10,000 gpm. The combined flow rate for one (1) RH pump and one (1) CSS pump has been calculated to be ~9,000 gpm
- The head loss due to chemical effects has been determined based on full chemical effects loading and maximum flow rates. Following an accident, the worst case head loss due to chemical effects will occur at temperature below 140°F; by the time the ECCS Sump water temperature decreases to this temperature, the flow from the ECCS Sump is expected to be reduced because, per procedure, CSS is shutoff after 8 hours.
- The strainer design maximum head loss is due to the maximum quantity (100%) of debris that was calculated to reach the screens, including chemical effects. Note the 140% chemical load only increases the head loss by less than 0.2 feet at design temperatures, maintaining acceptable margin.
- The total head loss was determined by adding the RMI head loss separately. This is conservative because RMI has been shown to result in a lower head loss when it is mixed with the other debris.
- These head loss numbers are based static pressures (i.e., conservative). When considering dynamic pressures (including the dynamic head), the calculated total head losses can be further reduced by 0.93 feet water column (WC).
- The probability of vortexing occurring in the ECCS Sump is further minimized by the fact that actual submergence levels, post-accident, would be significantly larger (28.8" to 49.6", refer to Response to Issue 3f2) than the maximum submergence level of the strainer module during the test (~1' maximum).

EGC Response to Issue 3f9:

The maximum clean water head loss through the scaled filtering assembly was measured to be 2.7 mbars (~1" of water). The head loss in the strainer assembly internal structures, including the waterbox and the waterbox to suction pipe interface assembly has been determined by the strainer vendor via CFD calculation. The software that was used is Computer Program ANSYS CFX10, Revision 10. This software has been validated in accordance with the CCI QA Program.

In case of a LOCA, debris is transported to the recirculation sumps. Considering a single failure of one ECCS train, the RMI debris is assumed to reach only one of the two sumps. The amount of the fine fraction of RMI is significant and it accumulates predominantly outside of the filter pockets. The other debris constituents tend to accumulate within the pockets. An important third contribution of head loss is created by flow in the internal cavities (including the waterbox upstream of the suction pipe) of the strainers. The flow paths upstream and downstream of the filtering surface are relatively complex and coupled, so an integrated CFD-simulation was done to gain a deeper understanding of the strainer flow and its head loss for the specified LOCA conditions.

An important key value to understand the flow behavior is the ratio of the head loss in the pockets to the head loss in the RMI. It describes whether the fluid flows directly through the upper part of filter or first enters the RMI bed and then flows through the filter.

For a low head loss coefficient in the pockets, almost all fluid flows through the RMI-free top rows of filter pockets. With an increasing flow resistance of the pockets the penetration depth of the fluid into the RMI also increases. Independent of the pocket head loss, a significant head loss occurs in the transition between strainer structure and suction pipe (i.e., the clean strainer head loss).

As part of the CFD simulation, the pocket flow resistance was varied parametrically and three different pressure loss coefficients of the filter pockets were defined and computed. The results show that the flow field and the head loss in the pockets and upstream of the pockets (RMI) depend significantly on the pocket head loss coefficients chosen. But the pressure loss downstream of the filter is more or less similar for each case, as shown in the table below:

Table 3f9-1
Pressure Loss (Pascals)

Pressure Loss	Medium Pressure Resistance	High Pressure Resistance	Low Pressure Resistance
Total Pressure Loss (Pa)	13,150	15,550	10,300
Pressure Loss Upstream of the Filter (Pa)	1,900	2,850	250
Pressure Loss in the Filter (Pa)	1,750	3,400	350
Pressure Loss in the Strainer Structure (Pa)	9,500	9,300	9,800

Sensitivity Study

The results discussed above are based on a hybrid mesh and water at 20°C. A sensitivity analysis was completed considering the effects of different mesh quality (pure hexahedral mesh vs. hybrid mesh) and fluid properties (water at 20°C, at 50°C and 95°C). Also, the impact of the turbulence model chosen (k-ε-RNG instead of k-ω-SST) was evaluated. The results of the sensitivity analysis show a deviation of < 3% and show that both the fluid temperature and the turbulent flow regime assumption only have a minor impact on the overall strainer pressure loss.

EGC Response to Issue 3f10:

The total head loss due to debris upstream of the ECCS Sump suction pipe includes the head loss contribution from:

1. RMI in the ECCS Sump pit
2. Debris within the strainer's pockets
3. Flow through the waterbox assembly, downstream of the filtering pockets, including the suction pipe entrance loss

RMI in the ECCS Sump Pit

Refer to the Response to Issue 3.f13 of this submittal for details on the head loss due to RMI debris in the recirculation ECCS Sump pit.

Debris within the strainer's pockets

Head loss within the strainer's pockets was determined via testing of a scale model of the filtering screens. In order to determine the limiting head loss test, the measured head losses were normalized to the same temperature (20°C).

Table 3f10-1
Normalized Head Losses

Test	Temp (°C)	Head Loss (mbar)	Head loss normalized to 20°C by viscosity of pure water (mbar)
1	19.3	69.4	68.1
4	28.6	66.5	82.3
5	29.4	65.4	82.4

The most conservative test is that with the highest normalized head loss, Test #5. Two additional factors are employed to adjust this value to actual field conditions, as described below.

1) The flow rate in MFTL tests is increased by 11.5% as it is expected that RMI outside the pockets produces the most significant head loss, and the tested pockets are shallower than those installed. However, the test surface area was scaled from the installed filter surface area. As laminar head loss is proportional to velocity, head loss is converted as follows: 65.4/1.115 = 58.7 mbar at 29.4°C.
2) The head loss value is scaled to other temperatures, including the design temperature of 200°F (93.3°C). This conversion is performed via changing viscosity as the head loss is proportional to this parameter.

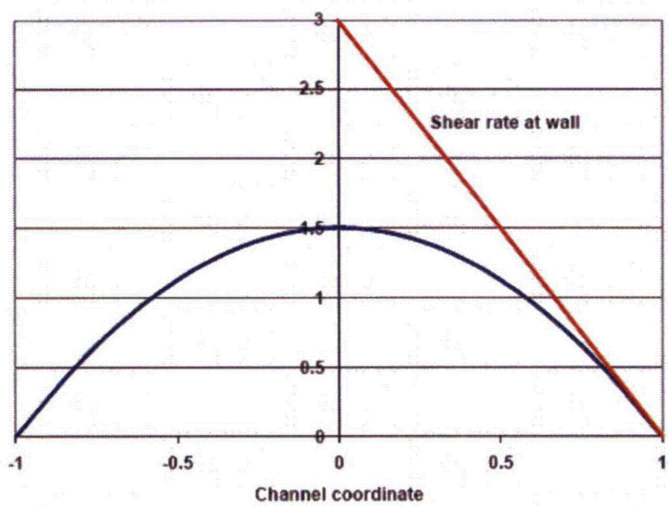
Typically, head loss would vary as a function of water temperature. However, data from the integrated chemical effects test (ICET) Test #1 indicates chemical effects play a role, the impact of which also varies by temperature. Therefore, a correction factor for head loss is applied:

$$f = \frac{HL_{ST}}{HL_{TT}} = \frac{\eta_{ST}}{\eta_{TT}} = \frac{\eta_{ST,p} * C_{ST}}{\eta_{TT} * C_{TT}}$$

where:
HL = head loss in mbar
η = dynamic viscosity in pascal-second (Pa*s)
C = factor of chemical influence on viscosity at constant temperature
index ST = scaled temperature
index TT = test temperature
index p = pure water

The chemical influence factor, C, is derived from ICET Test Report 1, which is the test most resembling Braidwood and Byron. The ICET Test Report represents viscosity in kinematic and dynamic viscosities. To select the appropriate viscosity values, an assessment is made of the shear rate in the debris layer in the field. The laminar flow in the debris layer is approximated by a channel flow with parallel boundaries with laminar velocity distribution. This is illustrated by the figure below where the x-axis represents side-to-side location in the pocket and y-axis is normalized velocity.

Figure 3f10-1
Flow Velocity as a Function of Channel Transverse Coordinate



If half channel width = x_0, and mean velocity = v_m, then:

$$v = 1.5 * v_m * \left[1 - \left(\frac{x}{x_0}\right)^2\right]$$

The governing shear rate determining drag to the wall and, subsequentally, head loss, is the derivation of velocity v, to the coordinate x at x_0. This yields the shear rate, SR:

$$SR = (3 * V_m) / x_0.$$

It is noted this velocity profile methodology is applicable to Newtonian fluids, and this application is non-Newtonian (viscosity decreasing with increasing shear rate). However, this is conservative for this application as wall shear rate is underestimated and for shear thinning fluid, low shear rates yield higher estimates of viscosities.

A typical channel width is of the same order of magnitude as the size of the debris in the bed – 5.5 microns for fiber and 10 microns for stone flour (representing coating and zinc particles). Therefore, channel width is taken as 10 microns and x_0 = 5 microns.

The maximum flow rate through the ECCS Sump screens, as installed in the field is 10,000 gpm, or 0.631 m^3/s. The area of the screens is 3020 ft^2, or 281 m^2. Thus, the velocity at the screen is 0.631/281 = 0.00225 m/s.

V_m is somewhat higher due to porosity of the debris bed, which is typically 0.75 for a thin debris bed. Therefore, V_m in the debris layer = 0.00225/0.75 = 0.0030 m/s. According to the shear rate equation above, SR is then 3 * 0.0030/5E-6 = 1800s^{-1}. This shear rate is two orders of magnitude higher than values for shear rate dependent date presented in ICET Test Report 1, section 4.5.6. The data shows a clear shear thinning effect, meaning viscosities are decreasing with increasing shear rates.

It is concluded the data from this section of the ICET Test Report is too conservative to be meaningful for this application. Therefore, data from section 4.5.5 (shear rate independent values) is employed to determine head loss for this application. The following explains the basis for this method.

The constant shear velocity measurements documented in section 4.5.5 were made with a Cannon-Feske capillary viscometer. The tube for this viscometer is size 50, which induces shear rates from 450 to 1790 s^{-1}. As lower shear rates provide higher viscosities, the previously calculated value of 1800 s^{-1} is conservative. Therefore, the viscosity measurements in section 4.5.5 of the ICET Test Report are appropriate for use.

Table 3f10-2
Viscosities

Viscosities (Pa*s) at 23°C and 25°C :

	23°C	25°C
Pure water (from [32])	0.000941	0.000900
Minimum from [27]	N/A	0.00093
Minimum from [28], chapter 4.5.5, Fig.36	0.959E-6*998= 0.000957	N/A
Factor c (Minimum)	1.017	1.033
Maximum from [27]	N/A	0.00131
Maximum from [28], chapter 4.5.5, Fig. 35	1.745-6*998= 0.001742	N/A
Factor c (Maximum)	1.851	1.455

Viscosity (Pa*s) at 60°C

	60°C
Pure water (from [32])	0.0004665
Minimum from [28], chapter 4.5.5, Fig.35	0.469E-6*983 = 0.000461
Factor c (Minimum)	0.988
Maximum from [28], chapter 4.5.5, Fig. 35	0.560E-6*983 = 0.000550
Factor c (Maximum)	1.179

where:

[27] is Chemical Test Filter Report 680/41222, rev. 2
[28] is LA-UR-05-0124, Integrated Chemical Effects Test Project: Test #1 Data Report, June 2005
[32] references water and steam tables

The four values for C from the table above are used to get bounding temperature relationships for C vs. temperature. The graph below shows these relationships which are obtained by linear interpolation between 23 and 60°C. Above 60°C, the maximum value is maintained constant. The impact of interpolating between these temperature values is minimal as the head loss margin in this temperature range is large.

The correction factor, f , is then conservatively maximized by using the minimum C value for the test temperature and the maximum C value for the scaled temperature. The interpolated minimum factor, C, and the viscosity for the relevant test temperature of 29.4°C become:

$C_{TT} = 1.012$
$\eta_{TT} = 1.012 * 0.000810 = 0.00082$ Pa*s

This value and values for maximum C are used to convert measured head loss of 65.4 mbar into head losses over the full range of temperatures. These are documented in the table below.

Table 3f10-3
Head Loss at Test Temperatures

Temperature	°C	23	60	100
Maximum Factor c		1.851	1.179	1.179
Minimum viscosity at test temperature	Pa*s	0.00082		
Head loss at test temperature	mbar	58.7		

	Scaled temperature	Pure water viscosity	Factor C	Viscosity	Head loss	
	°C	Pa*s		Pa*s	mbar	feet WC
	23	0.000941	1.851	0.0017418	124.69	4.17
	30	0.0007977	1.7238649	0.0013751	98.44	3.29
	40	0.0006532	1.5422432	0.0010074	72.11	2.41
	50	0.000547	1.3606216	0.0007443	53.28	1.78
	60	0.0004665	1.179	0.00055	39.37	1.32
	70	0.000404	1.179	0.0004763	34.10	1.14
	80	0.0003544	1.179	0.0004178	29.91	1.00
	90	0.0003144	1.179	0.0003707	26.54	0.89
Design temperature	93.333	0.0003035	1.179	0.0003578	25.62	0.86
	100	0.0002817	1.179	0.0003321	23.78	0.79

<u>Flow through the waterbox assembly, downstream of the filtering pockets, including the suction pipe entrance loss</u>

Refer to the Response to Issue 3.f9.

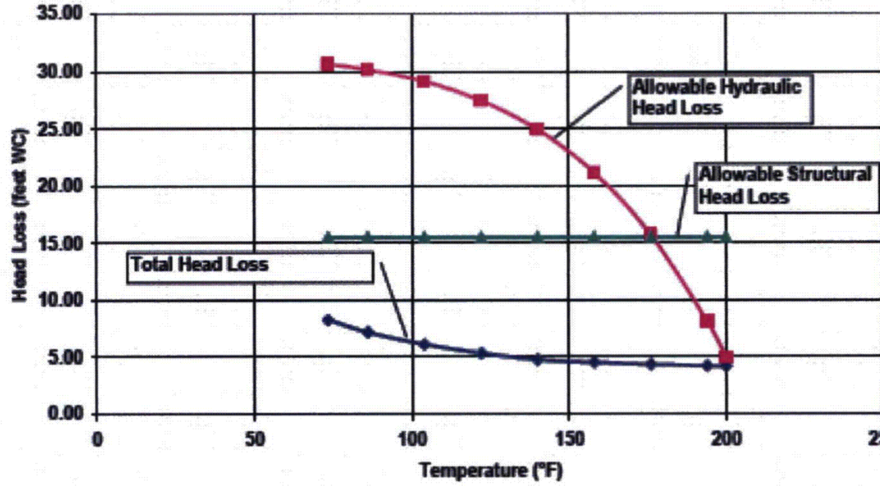
The total head loss through the ECCS Sump screens is given below:

Table 3f10-4
Overall Head Loss

Overall head loss

	Scaled temperature		Pocket head loss	RMI head loss	Internals head loss	total head loss		allowable	allowable struc
	°C	°F	mbar	mbar	mbar	mbar	feet WC	feet WC	feet WC
	23	73.4	124.69	28.55	94.24	247.48	8.27	30.64	15.54
	30	86	98.44	22.54	94.24	215.22	7.20	30.16	15.54
	40	104	72.11	16.51	94.24	182.87	6.11	29.11	15.54
	50	122	53.28	12.20	94.24	159.72	5.34	27.45	15.54
	60	140	39.37	9.02	94.24	142.63	4.77	24.91	15.54
	70	158	34.10	7.81	94.24	136.15	4.55	21.16	15.54
	80	176	29.91	6.85	94.24	131.00	4.38	15.74	15.54
	90	194	26.54	6.08	94.24	126.85	4.24	8.13	15.54
Design temperature	93.33	200	25.62	5.87	94.24	125.72	4.20	5	15.54
	100	212	23.78	5.44	94.24	123.46	4.13		15.54

Figure 3f10-1
Total Head Loss and Allowable (feet WC)



EGC 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.

EGC Response to Issue 3f12:

The chemical effects test procedure required that the debris be introduced directly in front of the surface of the strainer. Therefore, no credit was taken for near-field effects. Moreover, very little sedimentation was observed during the Multi-Functional Test Loop (MFTL) testing.

EGC Response to Issue 3f13:

The total head loss upstream of the ECCS Sump suction pipe includes the head loss contribution from:

1. RMI in the ECCS Sump pit
2. Debris within the strainer's pockets
3. Flow through the waterbox assembly, including the suction pipe entrance loss

Scaling factors were applied as discussed below:

RMI in the ECCS Sump pit

The head loss due to RMI was modeled in the testing to closely match field conditions by configuring the test loop to create a partially vertical flow field. Some of the tests have shown a decreased head loss when RMI is mixed with the debris. The last design basis test was done conservatively and the RMI was the last debris that was added in the loop. This modified sequence negated the positive impact of the RMI on head loss and effectively superimposed the RMI head loss to the head loss of the debris bed already on the screen.

A CFD analysis of the ECCS Sump pit showed that there exists a relationship between the RMI head loss and the flow resistance within the pockets. The higher the resistance in the pockets, the more the flow is forced to not only flow through the upper filter pockets that are RMI free, but also more flow is forced through the outer RMI layer (i.e., in the ECCS Sump pit), thereby creating higher RMI head loss. Therefore, the RMI head loss was converted from the test data that showed the highest pocket debris head loss, using a scaling factor that was derived using the RMI only head test data.

The RMI head loss is not adjusted for temperature. The theoretical RMI head loss from the GR, section 3.7.2.3.1.2, equation 3.7.2-8, shows that the head loss due to RMI is proportional to the square of the approach velocity and is not dependent on the viscosity of the water. Therefore, the RMI head loss is independent of water temperature for a given flow velocity field and RMI head losses need not be corrected for temperature differences.

Debris within the suction strainer pockets

The test case that resulted in the highest head loss within the pockets (including chemical effects) was taken as the design basis test case. Test #5 from the MFTL test resulted in the highest head loss within the pockets, due to fibers, particulates and chemicals effects. The comparison of the head losses between different test cases was made by normalizing the measured head loss from each test case at the test temperature to a temperature of 20°C.

The flow rate in the MFTL tests was increased by 11.5% due to the fact that the tested pockets were shallower than the pockets installed in the plant. However, for the head loss inside the pockets, the tested filter surface area was scaled from the proposed installed filter surface area. Since this laminar portion of head loss is proportional to velocity, the measured head loss was adjusted by the scaling factor of 1/1.115.

The measured head loss was scaled to the temperature range of interest using the viscosity, since for laminar flow, the head loss is proportional to viscosity.

Normally, the viscosity is known as a function of temperature for pure water. In this case, however, the chemical effects also affect the viscosity. Data from the Los Alamos ICET Test #1 shows that this factor is dependent on temperature. Therefore, CCI calculated an overall correction factor to account for temperature and viscosity changes. The viscosity change due to temperature was adjusted by the chemical effects correction factor and the resulting ratio was used to adjust the head loss that was measured at the test temperature.

Head Loss through the waterbox assembly, including the suction pipe entrance loss

The head loss within the strainer internal assembly was not adjusted for temperature changes. The head loss in the strainer internal structure was determined via CFD analysis. This analysis concluded that the flow through the strainer internal assembly, including the suction pipe entrance, is turbulent and thus independent of viscosity and temperature.

Braidwood and Byron are predominately RMI plants and do not have sufficient fiber quantities to cover the entire surface area of the ECCS Sump screens. Bore holes formation is not expected for Braidwood and Byron due to the small quantity of fiber and the large quantity of RMI debris that is postulated to reach the screens.

EGC Response to Issue 3f14:

The containment accident pressure is used in the water flashing evaluation. The available containment pressure was determined using the minimum and maximum safety injection double ended pump suction line breaks for Braidwood and Byron from the UFSAR. No changes have been made to the design analyses that support containment integrity.

The head loss calculation establishes flashing will not occur across the strainer surface. This is achieved by showing absolute pressure after the screen is always higher than the vapor pressure of the ECCS Sump water, factoring in changing water temperature. The head loss calculation compares said pressures for each unit, under maximum and minimum safety injection conditions. The minimum difference between absolute pressure after the screen and vapor pressure was calculated as 0.88 bars, or 29.4 feet of WC. This is significantly higher than any of the calculated debris head loss values. Given this result, it is established that flashing does not occur across the strainer surface.

NRC Question 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.*

EGC Response to Issues 3g1 and 2:

Each containment ECCS Sump feeds one train of the ECCS and one train of the CSS. When the ECCS switchover from the RWST to the ECCS Sump is completed, the RH pump for each train takes suction from the train specific ECCS Sump. Later into the event, the suction to the CSS pump for each train is switched to the ECCS Sump. The maximum flow rate from the ECCS Sump occurs when each train's RH and CSS pump take suction from the ECCS Sump.

For the Braidwood CSS pumps, 5,000 gpm is the flow rate used in the NPSH analysis. For the Byron CSS pumps, 4,800 gpm is the flow rate used in the NPSH analysis. These flow rates bound the maximum calculated CSS pump flow rate of 4,500 gpm CSS pumps.

The suction friction losses are determined based on flow rates of 5,000 gpm for the RH pumps and 5,000 gpm for the CSS pumps.

These flow rates include the eductor motive and additive flows. The portion of this flow rate from the ECCS Sump is the above flow rate with the motive and additive flows removed. The eductor motive and additive flows (as measured by an ultrasonic flowmeter located upstream of the containment spray additive throttle valve) are set to values targeted in the Containment Spray Additive Flow Rate Verification Procedures.

The maximum flow rate from the ECCS Sump to the RH pump is 5,000 gpm in the analysis. This is the maximum flow rate on the RH pump vendor curves. This bounds the maximum flow rate of 4,533 gpm, which was measured in a pre-operational test at Braidwood for the RH pumps in recirculation mode.

The maximum Head Loss for the replacement screens is applicable to a maximum ECCS Sump flow rate of 10,000 gpm. No credit is taken for reduction of flow from the ECCS Sump. The total ECCS Sump flow that was used in the NPSH analysis is 10,000 gpm for Braidwood and 9,800 gpm for Byron.

Minimum Containment Flood Level

The minimum flood levels that are used in the NPSH analysis are as follows:

- 9.2" at the time the suction to the RH pumps is switched over to the ECCS Sump.
- 25.6" at the time the suction to the CSS pumps is switched over to the ECCS Sump.

The containment floor elevation at both Braidwood and Byron is considered 377' 0".

Water Temperature

The suction friction losses have been calculated using a water temperature of 120°F. The friction losses were adjusted to account for higher fluid viscosity resulting from chemical effects. The maximum viscosity (kinematic) increase factor due to the chemical effects in fouled ECCS Sump water is 1.9.

The NPSH analysis is done for a temperature range of 73.4°F to 260°F. For temperatures above 200°F, the containment pressure is taken to be equal to the ECCS Sump fluid vapor pressure. For temperatures below 200°F, the initial containment air pressure is credited.

EGC Response to Issue 3g3:

The NPSH required ($NPSH_R$) values are taken from the bounding pump vendor curves. NPSH available ($NPSH_A$) testing would have been completed in accordance to the Hydraulic Institute guidelines in effect at the time of the pump manufacture. Typically the 3% head drop criterion was used for all $NPSH_A$ testing.

Table 3g3-1
NPSH Required for Design Basis Maximum Flow Rates

Pump	Flow Rate (gpm)	$NPSH_R$ (ft)
Braidwood CSS Pumps	5,000	23.0
Byron CSS Pumps	4,800	22.5
RH Pumps	5,000	19.1

These flow rates bound the maximum CSS pump flow rate (< 4,500 gpm) and the maximum RH pump flow rate (4200 gpm). Also, the RH flow rate bounds the maximum flow rate of 4,533 gpm, which was measured in a pre-operational test at Braidwood for the RH pumps in recirculation mode. The table below gives the NPSH required values for the highest expected flow rates.

Table 3g3-2
NPSH Required for Expected Flow Rates

Pump	Maximum Flow Rate (gpm)	$NPSH_R$ (ft)
Braidwood CSS Pumps	4,500	20
Byron CSS Pumps	4,500	21
RH Pumps	4,500	17.3

Thus, an additional NPSH margin is gained when the actual flow rates are considered.

EGC Response to Issue 3g4:

The suction line losses for the CSS and RH paths were first computed using an integrated hydraulic model for bounding containment and ECCS Sump conditions (i.e., minimum temperature and pressure; maximum temperature and pressure). The NPSH analysis used flow rates higher than calculated. As a result the head loss due to friction was increased; first the head losses from the case that has the highest friction factor are found. These head losses were scaled to the flow rates used in the NPSH calculation by using Crane Technical Paper 410.

To determine the effect of the increase in viscosity due to chemical effects, only the losses in pipe sections are scaled. The resistance coefficient (K) in fittings is determined based on the shape of the fitting, as described in Appendix A of Crane Technical Paper 410. This means that increasing the viscosity of the fluid moving through these fittings will not change the head loss through the fitting. For the piping sections, the friction factor was adjusted and the head loss was recalculated.

EGC Response to Issues 3g5 and 6:

In response to a LOCA, the residual heat removal (RH), centrifugal charging (CV), and safety injection (SI) pumps automatically start upon receipt of a safety injection signal. These pumps inject to the reactor coolant system cold legs, taking suction from the refueling water storage tank (RWST). This system line-up is referred to as ECCS Injection phase. The Containment Spray (CSS) pumps start automatically when the containment pressure reaches the setpoint for CSS actuation; the CSS pumps also take suction from the RWST. The switchover to the ECCS recirculation sumps as suction source to the RH pumps is initiated when the RWST water level decreases to approximately 47%.

After the ECCS recirculation line-up is established, the RH pumps combine to inject to the RCS cold legs and to supply water to the suction of the CV and SI pumps. The CV and SI pumps continue to inject to the RCS cold legs. This line-up is referred to as ECCS Cold Leg Recirculation. At approximately 6 hours into the event, the ECCS line-up is modified for Hot Leg recirculation. The RH pumps supply the suction to the CV and SI pumps and inject to the RCS hot legs. The SI pumps also inject to the RCS hot legs while the CV pumps continue to inject to the RCS cold legs.

The CSS pumps continue to take suction from the RWST until the suction source is manually switched over to the ECCS recirculation sumps when the RWST water level decreases to approximately 12%.

The above describes the design response for the ECCS and the CSS to a LOCA. The differences between the response to a Large Break LOCA and a Small Break LOCA are:

- Depending on the size of the break, the RCS pressure may stabilize at a value that does not allow injection from the RH pumps and the SI pumps.
- In SBLOCA scenario, the containment accident pressure will likely remain below the actuation setpoint for CSS.

In a SBLOCA, the outflow from the RWST may be sufficiently low that the plant may be taken to a safe shutdown condition before the RWST level setpoint for ECCS switchover is reached. Additionally, the quantity of debris that is generated in a SBLOCA scenario is a fraction of the design basis debris quantity that was used to size the screens.

EGC Response to Issue 3g7:

The Braidwood and Byron design includes two separate containment recirculation sumps, fully redundant, each servicing one train of the ECCS. Replacement screens have been installed in each sump; in order to satisfy the single failure criteria (one ECCS train does not start), each screen has been sized to accommodate the maximum volume of debris that is predicted to arrive at the sump screen.

EGC Response to Issue 3g8:

The flood level is determined by a mass balance that includes the inputs from the reactor coolant system, refueling water storage tank, and safety injection accumulators. Water volumes entrapped are not included in the total water volume.

The containment recirculation sumps (one for each train of ECCS and CSS) are located inside the containment building, below floor elevation 377 ft. The water level in the ECCS Sump is assured by post-LOCA containment flood level that is above floor elevation 377 ft. The results of the minimum containment flood level calculation are given in height above containment floor elevation 377 ft. The results of the minimum containment flood analysis show a minimum flood level at ECCS switchover of:

- SBLOCA – 4.8"
- LBLOCA – 9.2"

At the time the CSS pumps' suctions are switched over to the containment recirculation sumps, the minimum containment flood level is as follows:

- SBLOCA – 21.2"
- LBLOCA – 25.6"

<u>EGC Response to Issue 3g9:</u>

The conservatism of the minimum containment water level is maintained by minimizing the sources of floodwater and by maximizing the volume of water entrapment.

Some of the specific examples of water sources that are minimized are given below:

- ECCS switchover and containment spray switchover are assumed to be instantaneous. This eliminates the increase in flood level during the switchover sequence.
- The minimum RWST volume from the beginning of the LOCA event to the start of ECCS switchover. This minimizes the water volume available from the RWST for flooding.
- The minimum RWST volume from ECCS switchover to the CSS switchover. This minimizes the water volume available from the RWST for flooding.
- The maximum RWST temperature is used to calculate the RWST water density. This minimizes the available mass in the RWST for flooding.
- The minimum RCS volume at full power is assumed prior to the LOCA. This minimizes the water available for flooding from the RCS.
- The maximum RCS temperature is used to calculate the density of the RCS water. This minimizes the available mass in the RWST for flooding.
- The minimum pressurizer volume is used. This minimizes the water available from the pressurizer for flooding.
- The minimum safety injection accumulator volume is used. This minimizes the water available from the safety injection accumulators for flooding.
- The minimum initial containment relative humidity is used. This minimizes the water vapor in the containment free volume available for flooding.
- The maximum initial containment temperature is used. With a fixed initial relative humidity and pressure, this minimizes the water in the containment air space available for flooding.
- Equipment in the flood zone does not contribute to the flood height.
- The volume from the Containment Spray Additive Tank is not considered.

Some of the examples for maximization of water entrapment are:

- The maximum containment net free volume is used. This maximizes the water vapor entrapped in the containment atmosphere post-LOCA.
- The minimum RCS temperature is assumed for the water that refloods the RCS. This maximizes the mass of the water entrapped in the RCS reflood volume.
- The minimum containment pressure is assumed for the vapor reflooding the RCS. This maximizes the water vapor mass entrapped in the RCS reflood.
- The maximum RCS volume at full reactor power is assumed during reflooding. This minimizes the mass of water available for flooding.
- The containment atmosphere is assumed to have 100% relative humidity post-LOCA. This maximizes atmospheric hold-up.
- The refueling cavity, up to the elevation of the reactor vessel flange, is considered an entrapment volume.
- The flooded refueling cavity is assumed to be at the temperature of the RWST, 120°F. This is conservative as it maximizes the amount of water entrapped in the refueling cavity, minimizing water available for flooding of the containment floor.
- CSS water is assumed to become saturated as it falls through the containment atmosphere. This results in an increased amount of water trapped in the refueling cavity, minimizing water available for flooding of the containment floor.
- No credit is taken for displacement of water from ECCS trash rack and ECCS Sump screens, or associated structural equipment
- The RCFC enclosures are assumed to leak. No credit is taken for a reduced rate of leakage from a weir effect. This is conservative as it maximizes the available flood area, reducing the calculated flood height.

EGC Response to Issue 3g10:

- The maximum heat sink surface area is used. This maximizes the water entrapped due to the condensation layer.
- The thickness of the condensate layer is equal to the layer computed to buildup at the bottom of a 50 ft height.
- The surface temperature of the heat sink is assumed to be equal to the initial containment temperature.
- Empty CSS pipe is accounted as a source of water entrapment.
- The minimum containment flood calculation assumes that the water transport time from the containment spray ring header to the ECCS Sump is negligible for the water that is not accounted for as entrapped as condensation on the heat sinks, water vapor in the containment free volume, water in the refueling cavity or water reflooding the RCS. This allows for the entire mass of water in containment to be accounted for, without determining the amount of falling water at any given time. The containment spray water that has not become entrapped will have a minimal transport time due to the high velocity of the water exiting the CSS nozzles. This assumption is justified because the water present as free volume was estimated to be approximately 0.5% of the total calculated floodwater.
- Water vapor in the containment atmosphere and condensation on passive heat sinks are considered as water entrapments.

<u>EGC Response to Issue 3g11:</u>

Displacement of water by equipment in the flood zone is not considered.

<u>EGC Response to Issue 3g12:</u>

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

- RCS – minimum volume used - 11,877 ft^3

  This volume includes Steam Generator tubes volume assuming 10% tube plugging. This volume is the minimum RCS volume for Braidwood, Unit 1 and Byron, Unit 1. Braidwood, Unit 2 and Byron, Unit 2 have a minimum RCS volume of 13,199 ft^3.

- RWST – minimum volume used from start of event to ECCS switchover- 180,888 gallons.

  The volume is determined by considering the volume available between the minimum RWST starting volume of 89% (required by Technical Specifications (TS) 3.5.4, "Refueling Water Storage Tank (RWST)") and the RWST LO-2 Level alarm (beginning of ECCS switchover sequence) of 46.7%, accounting for a 2.8% differential level uncertainty.

- RWST – minimum volume used from ECCS switchover to CSS switchover – 146,084 gallons.

  The volume is determined by considering the volume available between the RWST LO-2 Level alarm (Beginning of ECCS switchover sequence) of 46.7%, and the 12% CSS switchover level setpoint, accounting for a 2.8% differential level uncertainty.

- Safety Injection Accumulators – minimum volume used - 27,973 gals.

  This volume corresponds to the minimum water level required by the TS (3.5.1, "Accumlators").

<u>EGC Response to Issues 3g13:</u>

Credit is not taken for containment accident pressure in determining the available NPSH.

<u>EGC Response to Issue 3g14:</u>

The NPSH analysis considers the containment air pressure that was present in containment before the accident (i.e., 14.17 psia). The NPSH analysis at high temperature (greater than the saturation temperature at the minimum initial air pressure, 203.9°F) sets the containment pressure equal to the vapor pressure corresponding to the ECCS Sump liquid temperature (highest temperatures from current plant analysis).

EGC Response to Issue 3g15:

The NPSH analysis for high temperature assumes the containment pressure is equal to the water vapor pressure of the ECCS Sump liquid temperature.

EGC Response to Issue 3g16:

Below is the final minimum NPSH margin (NPSH Available minus NPSH Required) above the CCI expected head loss:

Table 3g16 – 1
Margin of the Limiting Head Loss Over the CCI Expected Head Loss

T_{sump} (°F)	Screen Head Loss (ft)	Margin over CCI Loss: RH Pumps (ft)	Margin over CCI Loss: Braidwood CSS Pumps (ft)	Margin over CCI Loss: Byron CSS Pumps (ft)
260.0	4.13	3.8	0.8	1.3
235.0	4.13	3.8	0.8	1.3
210.2	4.13	3.8	0.8	1.3
203.9	4.20	3.7	0.7	1.2
200.0	4.20	3.7	0.7	1.2
175.0	4.38	7.6	11.0	7.6
158.0	4.55	11.0	10.8	11.0
140.0	4.77	10.8	10.2	10.8
122.0	5.34	10.2	10.2	10.2
104.0	6.11	9.4	9.4	9.4
86.0	7.20	8.3	8.3	8.3
73.4	8.27	7.3	7.3	7.3

Notes:

- The screen vendor reports the screen head loss calculation at specific temperatures up to a maximum of 212°F. For temperatures greater than 212°F, the screen head loss is conservatively assumed to be 4.13 ft, the value for expected head loss at 212°F. No credit is taken for lower head loss due to lower viscosity at higher temperatures.
- The suction piping friction losses that have been used in the calculation of available NPSH have been determined based on maximum flow rates that are larger than calculated. This assumption accounts for approximately 1 ft of margin.
- The suction piping friction losses that have been used in the calculation of available NPSH have been determined based on the maximum calculated increase in viscosity due to chemical effects. The maximum viscosity increase does not apply to temperatures above 140°F.
- The NPSH required values that were used in the NPSH analysis were taken at maximum pump flow rates (Reference Response 3g.3).

Thus, additional NPSH margins are gained when the actual flow rates are considered.

NRC Issue 3h:

Coatings Evaluation

The objective of the coatings evaluation section is to determine the plant-specific ZOI 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 ZOI 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.*

EGC Response to Issue 3h1:

Coating systems used in containment are described in Braidwood - Byron UFSAR, Chapter 6.1.2.

Steel containment

A prime coat of inorganic zinc-rich coating and a finish coat of phenolic organic coating are applied. The prime coat is Carboline Carbozinc 11SG, 3 – 6 mils thick. The finish coat is Carboline Phenoline 305, 4 – 6 mils thick.

Concrete walls and steel embedded in walls

One epoxy surface coat is applied over formed concrete wall and ceiling surfaces, and over concrete masonry wall surfaces. One phenolic finish coat is applied over the surfacer coat. The surfacer coat is Carboline Surfacer 195, 20 – 30 mils thick. The finish coat is Carboline Phenoline 305, 4 – 6 mils thick.

Concrete floors and steel embedded in floors

One epoxy prime coat and one phenolic finish coat are applied over finished concrete floors and miscellaneous steel embedded in the floor. The surfacer coat is Carboline Surfacer 195, 20 – 30 mils thick. The finish coat is Carboline Phenoline 305, 6 – 8 mils thick. All coatings are cured at ambient temperature, not less than 60°F.

The unqualified coatings quantities include the original equipment manufacturer (OEM) of the coatings and a number of coatings that are considered not qualified due to deficiencies in the application process. A conservative dry film thickness of 8 mils was assumed in the debris generation analysis. Since details of the coatings types are not available for all unqualified coatings, the debris generation analysis assumes that 100% of the unqualified coatings fail. No credit is taken for reducing this quantity based on the results of EPRI OEM Coatings testing.

EGC Response to Issue 3h2:

Per Section 3.4.3.2 of the GR, all qualified coatings within the ZOI are considered small fines. This size is also conservatively applied to all unqualified coatings outside the ZOI in accordance with the SE. Therefore, 100% of coatings debris is modeled as transporting to the ECCS Sump screen, which is consistent with the NRC position that all coatings debris are highly transportable particulate. No credit is taken for debris holdup in inactive containment volumes.

EGC Response to Issue 3h3:

The following materials were used in the CCI head loss testing to represent the coating debris term as discussed in the Response to Issue 3f4:

- Stone flour for Qualified Epoxy Coating
- Zinc Dust for Inorganic Zinc and Unqualified Coatings

EGC Response to Issue 3h4:

The basic justification for using stone flour is based on the assumption that an average particle size of 10 μm with the same total volume occupation is characterizing the typical head loss characteristic based on the S_v value equivalence. There is a density difference between the original and the surrogate material. As far as the appropriate particle quantity is concerned, the surrogate material quantity was based on the same volume as the original. The weight for the tests therefore was determined with the surrogate density, which guaranteed the correct volume quantity for head loss.

The density difference can, in principle, also affect the settling of the debris before it gets to the strainer pockets. However, the particulates which were used in the tests were only partly from stone flour. A significant portion was zinc dust, which was not substituted by a surrogate. It was not practical to separate settling effects of the two particulates. Since stone flour was only a part of particulates, the significance of its settling behavior is relatively low. This is also backed up by the observation that very little settling occurred in the MFTL tests.

Note that the quantity of qualified epoxy coating that was an input to the head loss testing was calculated using a qualified coating ZOI of 10D. This quantity is approximately seven (7) times larger than the quantity calculated with a ZOI of 5D. Considering the procedural requirement to introduce the debris in front of the test module, combined with the extremely conservative quantity of epoxy debris used in the test, it is concluded that the test with the stone flour as a surrogate material for qualified epoxy coating is considered to adequately model the actual conditions for Braidwood and Byron.

Moreover, within the size spectrum of the stone flour, (which corresponds to a respective spectrum for the real coating) the important head loss contributing portion is the small size fraction. The settling differences primarily only affect the larger particles of the spectrum, however, they also contribute negligibly to head loss because of their low S_v value contribution. The chemical effects test has shown that dissolution or chemical reactions of stone flour is negligibly small.

Inorganic Zinc Particulates

For testing IOZ (both qualified and unqualified), zinc filler for IOZ coatings was ordered from Carboline per EGC specifications. The mass of the zinc dust needed for the testing was calculated using the volume of IOZ coating and a particulate density of 457 lbm/ft^3. The particulates are characterized by a sphere diameter of 10 μm (e.g., the GR, Table 3-3, coating debris characteristics). Since this is a theoretical value and real available particulates always have a size distribution spectrum, CCI choose to use a surrogate particulate product for IOZ with the same Sv value as a theoretical product with just only spheres of 10 μm. The Sv value of spheres at 10 μm is equal to 6/1.E-5 (600,000 m-1 or 0.6 m^2/cm^3). The S_v value is 0.573 m^2/cm^3, which corresponds to a sphere diameter of 10.5 μm. This was a measured value at the time of the testing, which is near 10μm.

EGC Response to Issue 3h5:

EGC has followed the guidance from the SE for determining the quantity of coating debris. Per section 3.4.2.1 of the SE:

- All coating (qualified and unqualified) in the ZOI will fail,
- All "qualified" (DBA-qualified or acceptable) coating outside the ZOI will remain intact,
- All "unqualified" coatings outside the ZOI will fail.

The Braidwood and Byron design basis debris term for qualified coating has been calculated based on a ZOI radius of 10D. It is recognized that the 10D ZOI assumption does result in significant conservatism. In fact, WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings," provides results of industry testing that support using a ZOI of 4D or greater for qualified epoxy coatings and a ZOI of 5D or greater for qualified untopcoated inorganic zinc coatings. In order to quantify the available margins, one debris generation case has been performed with a 5D ZOI applied to epoxy coatings, and a 10D ZOI applied to inorganic zinc coatings. The results of these analyses show that the total coating debris generated with a reduced ZOI is about 1/3 of the coating debris generated with a ZOI of 10D.

The Braidwood and Byron design basis debris term assumes that 100% of the unqualified coatings fail. This assumption is in compliance with the SE.

Due to the fact that specific information is not available on all the specific OEM coating types, no credit is taken for reducing the percent of unqualified coatings that are assumed to fail.

EGC Response to Issue 3h6:

As described in Response to Issue 3f4, a number of tests were done to understand the influence of replacing the coating particles by paint chips. The results indicated that it was more conservative to model coatings as fine particles in the testing program.

Zinc Dust vs Stone Flour

Two tests (Tests #1 and #2) were performed prior to the chemical tests. The unqualified coatings quantities were modeled by IOZ and zinc dust in Test #1 and by epoxy and stone flour in Test 2. Test 1 showed a 50% higher head loss than Test #2 (68.7 vs. 45.8 mbar). Therefore, IOZ and zinc dust was used for the chemical test as unqualified coating for conservatism in the remaining tests.

EGC Response to Issue 3h7:

The acceptability of visual inspection as the first step in monitoring of Containment Building coatings is validated by EPRI Report No. 1014883, "Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level 1 Coatings," August 2007. Monitoring of Containment Building coatings is conducted at a minimum, once each fuel cycle in accordance with Braidwood and Byron procedures based on ASTM D 5163, "Establishing Procedures to Monitor the Performance of Safety-Related Coatings in an Operating Nuclear Power Plant."

Monitoring involves conducting a general visual examination of all accessible coated surfaces within the Containment Building, followed by additional nondestructive and destructive examinations of degraded coating areas as directed by the plant Protective Coatings Specialist. Examinations and degraded coating inspections are conducted by qualified personnel as defined in EGC procedure ER-AA-330-008, "Exelon Service Level I, and Safety-Related (Service Level III) Protective Coatings," recommended by ASTM D 5163. Detailed instructions on conducting coating examinations, including deficiency reporting criteria and documentation requirements are delineated in EGC procedure ER-AA-330-008.

NRC Issue 3i:

i. 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*

EGC Response to Issues 3i1, 3i2, and 3i3:

Braidwood and Byron have a "Containment Loose Debris Inspection," procedure. The procedures outline the steps necessary to verify the containment is free of loose debris, fiber, and foreign material. It is applicable for all accessible areas just prior to establishing Containment Integrity. It is also applicable for affected areas at the completion of any Containment entry when Containment Integrity is already set.

The procedures for containment closeout specify that a containment walkdown be performed for housekeeping deficiencies. The procedure incorporates a list of all unresolved housekeeping and equipment discrepancies and requires that resolution be included in the plant restart documentation. The procedure also provides guidance on general cleanliness and debris inspection guidelines.

EGC Response to Issue 3i4:

An enhancement was made to the Design Attributes Review (DAR) document that is part of the Configuration Change Procedure. This change introduces a requirement to review the impact of a proposed change on the documentation that forms the design basis for the response to Generic Letter 2004-02. The specific areas that are addressed are:

- Insulation inside containment
- Coatings inside containment
- Inactive volumes in containment
- Labels inside containment
- Structural changes (i.e., Choke points) in containment
- Downstream Effects (piping components downstream of the ECCS Sump screens)

Inclusion in the DAR will ensure all design changes consider these attributes during the design process.

Latent Debris

Braidwood and Byron created a recurring activity to perform latent debris measurements on a frequency of every four refueling outages (nominally, a six-year frequency). The results of this walkdown/measurement will be evaluated/incorporated in the design analysis for the ECCS Sump screens.

Downstream Effects

Any hardware changes potentially affecting the downstream effects analysis are controlled via the configuration change process.

Labels

Braidwood and Byron have upgraded the Labels and Tagging procedure to incorporate processes to ensure the design bases is preserved.

Choke Points/Water Holdup

Included in the loose debris inspection procedure is a requirement to verify both screen doors between inside missile barrier (IMB) and outside missile barrier (OMB) areas are not blocked and debris is not present in the vicinity of the doors that represent a risk for blockage of the screen doors. This requirement is applicable to anyone traversing plant elevation 377 during Operating Modes 1-4. This ensures the flow paths for water from the OMB to IMB are unblocked.

In summary, Braidwood and Byron have implemented the necessary programmatic and process controls to ensure the recirculation function will be maintained into the future.

EGC Response to Issues 3i5:

Maintenance activities, including temporary changes are subject to the provisions of 10 CFR 50.65(a)(4) as well as Braidwood and Byron TS. EGC fleet procedures also provide guidance such as the 50.59 Review Process procedure, which provides details and guidance on maintenance activities and temporary alternations, the on-line work control process procedure, which establishes the administrative controls for performing on-line maintenance of structures, systems, components (SSC) in order to enhance overall plant safety and reliability, and the Temporary Configuration Changes (TCC) procedure, which establishes the overall requirements for TCC. No suggested design or operational refinements given in the GR or the SE were used or applied in the procedures that govern maintenance activities, including temporary changes.

EGC Response to Issues 3i6 and 7:

Braidwood, Unit 1 and Byron, Unit 1 have reduced the debris source term by replacing fiber insulation that was located within its specific ZOI. The fiber insulation was replaced with RMI from Transco. The steam generators and connected piping were insulated with thermal wrap type insulation manufactured by Transco when the Steam Generators were replaced in 1997. The thermal wrap insulation consisted of fiberglass enclosed in blankets that were covered with stainless steel sheathing. Removal of the insulation did not require breaking the blankets that enclosed the fiberglass. Thus, the insulation replacement did not result in the creation of fine debris that would increase the latent debris source term. The Braidwood and Byron replacement screens have been sized based on the reduced debris source term. As stated earlier, Braidwood, Unit 2 and Byron, Unit 2 required no insulation change-out, as they have always been RMI units.

EGC Response to Issues 3i8:

There were no other modifications to equipment or systems conducted to reduce the debris burden at the ECCS Sump strainers at Braidwood and Byron.

EGC Response to Issues 3i9:

Braidwood and Byron have an existing coatings program that monitors and controls the quantities and types of coatings installed inside containment. As noted in the EGC response to GL 98-04[3], Braidwood and Byron have 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.

[3] Letter from R. M. Krich (Commonwealth Edison Company) to U. S. Nuclear Regulatory Commission, "Response to NRC 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 Construction and Protective Coating Deficiencies and Foreign Material in Containment,'" dated November 12, 1998

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.*

EGC Response to Issue 3j1

The new ECCS Sump screens within each ECCS Sump pit are comprised of two banks of filtering equipment (see Figure 3k2 - 1 in Response to issue 3k2). The openings in the new screens are nominal 1/12" in diameter. The filters' assemblies consist of perforated stainless steel plates, assembled to form pockets, which feed a water box that is connected to the ECCS Sump suction pipe. The overall screen surface area is 3020 ft^2, and represents the maximum amount of screen area that could be placed within each ECCS Sump pit per the CCI design.

The original 3/8" mesh screens were replaced with Stainless Steel Grating (i.e., the trash rack) with nominal 2" by 1" openings (actual opening size 1-7/8" x 7/8"). In addition, there are openings in most of the sectors of grating that are located approximately 5 1/2" above the floor to act as a weir ensuring that there is sufficient flow area to maintain adequate water flow to support the operation of the RH and CSS pumps. Finally, there is a debris protection plate installed at the bottom of each weir opening in the trash rack which limits debris from entering these open areas.

EGC Response to Issue 3j2

A short (nominal 2") curb is installed around the perimeter of the modified trash rack. This short curb ensures online leakage in containment will reach the leakage detection sumps rather than entering the ECCS sumps. Prior to installation of the new sump screens, there was a single level switch assembly inside each sump. The assembly transmitted a signal to the main control room, indicating water level in the sump. The assembly was downstream of the old screens and aided in diagnosing differences between sump and containment water levels. Such a difference indicated potential clogging of the old screens. The assembly was not EQ qualified and not used to actuate ECCS equipment. Due to interference with the new screens, the assembly was removed and associated cables removed and/or abandoned in place, including indicating lights in the control room. Had the assembly remained in place, it would have been upstream of the new screens. This would have made it unable to diagnose potential screen blockage and redundant with existing EQ-qualified and safety related containment water level instrumentation. Thus, the assembly was not functional or necessary.

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.

EGC Response to Issue 3k1:

As stated in the Response to Issue 3j above, the new ECCS Sump screens within each ECCS Sump pit are comprised of two banks of filtering equipment. The openings in the new screens are 1/12" in diameter. The filters' assemblies consist of perforated stainless steel plates, assembled to form pockets, which will feed a water box that is connected to the ECCS Sump suction pipe.

The new CCI cassette ECCS Sump strainers installed at Braidwood and Byron (see sketch below) include the following components.

- Strainer support structure
- Standard strainer cartridge
- Short strainer cartridge
- Support struts for the strainer

The new screen assemblies are installed and fill most of the volume of the existing ECCS Sump pits. The screen assembly is not anchored to the floor of the ECCS Sump pit. However, there are struts near the ECCS Sump pit floor, which extend from each side of the screen base frame towards the surrounding walls with a gap of 3/16" between the plate at the end of the strut and the wall. In addition, there are struts to connect the top of the screen assemblies that are anchored to the ECCS Sump pit ceiling just within the three openings through the floor. These supports are designed to limit the movement of the structure within the ECCS Sump pits. These struts are designed for the seismic loads that the screen assembly may encounter.

The structural adequacy of the ECCS Sump screens is verified in an EGC calculation for both Braidwood and Byron. The analysis of the ECCS Sump screen components was performed using ANSYS, ANSYS "Workbench" and ANSYS "Design Modeler", all Revision 10.

The design basis loads considered in the verification included postulated weight of debris and pressure differential, in addition to screen self weight and seismic loads. Dynamic effects due to loads imposed by expanding jets and missiles caused by design basis pipe breaks were not considered. The justification for not including these loads in the verification is described in the Response to Issue 3k.3 below.

The trash racks are designed for hydrostatic loads, hydrodynamic loads (including effects of sloshing), impact loads of insulation debris, and drag loads, in addition to dead and seismic loads.

Summary of Design Inputs

- Minimum ECCS Sump water temperature during recirculation - 70°F
- Maximum ECCS Sump water temperature during recirculation - 260°F
- Maximum containment air temperature - 333°F
- Allowable head loss at 200^0 F - 5 ft.
- Maximum head loss - 15.54 ft.
- Maximum pressure differential - 6.723 psi
- Total weight of debris distributed over strainer - 2205 lbs

Summary of Design Codes

- AISC Manual of Steel Construction, sixth edition
- ASME Boiler and Pressure Vessel Code Section II, Part D – Properties
- ASME Boiler and Pressure Vessel Code Section III, Subsection NF – Supports

Summary of Design Loads

D - Dead load
P_a - Pressure differential
E - Seismic OBE
E' - Seismic SSE

Summary of Design Load Combinations

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

Table 3k.1
Load Combinations and Acceptance Criteria Used in ECCS Sump Screen Verification

Load Condition	Temperature, °F	Load Combination	Acceptance Criteria
Normal	120°	D	AISC normal allowables
Severe Environmental	120°	D + E	AISC normal allowables
Extreme Environmental	120°	D + E'	1.6 times AISC normal allowables
Abnormal/Severe Environmental	70°-260°	D + Pa + E	1.6 times AISC normal allowables
Abnormal/Extreme Environmental	70°-260°	D + Pa + E'	1.6 times AISC normal allowables

<u>EGC Response to Issue 3k2:</u>

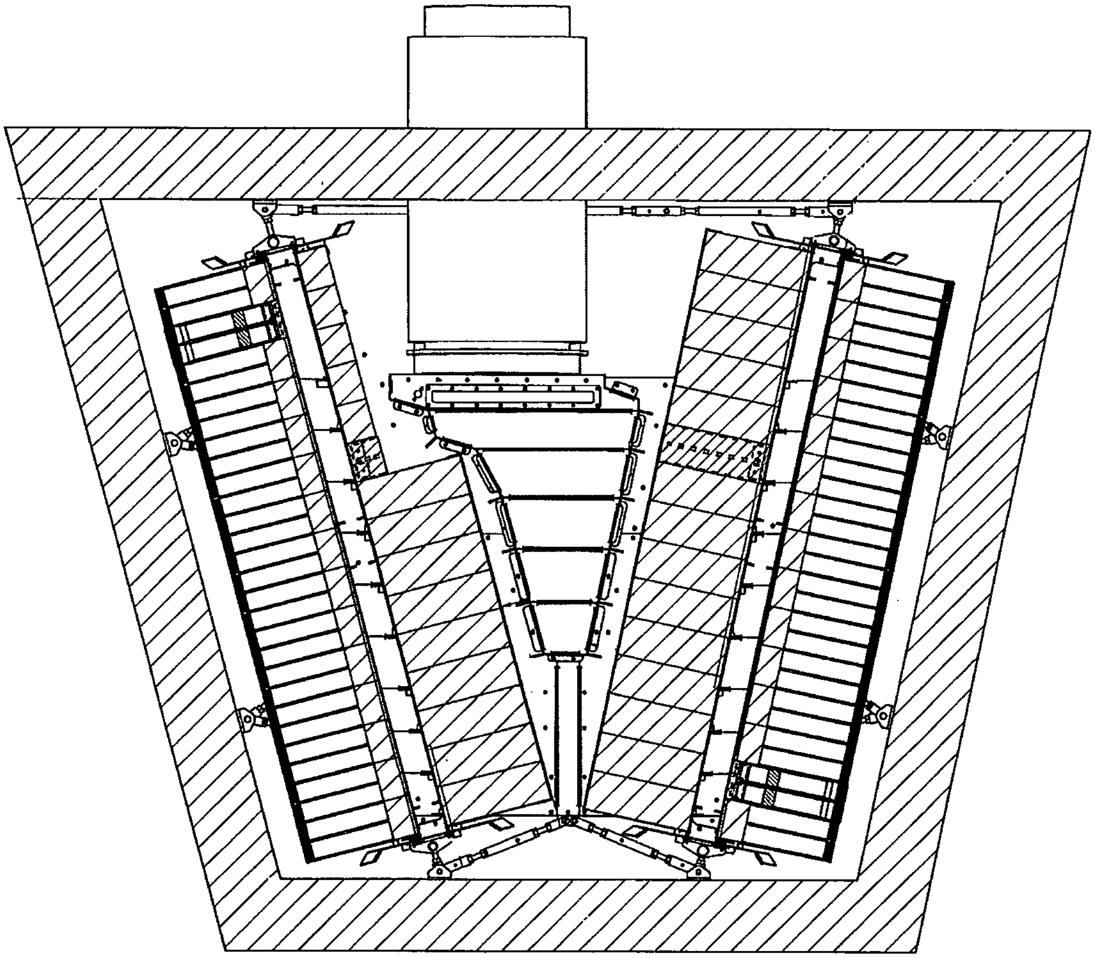
The ratios of design stress and corresponding allowable stress for the various components of the ECCS Sump strainer structural assembly are presented in Table 3k2 - 1 below.

Table 3k2 - 1
Ratios of Design Stress and Corresponding Allowable Stress for Various Components of ECCS Sump Strainer Structural Assembly

Serial No.	Component	Component Element	Maximum Stress Ratio
1	Standard Cartridge	Non-perforated Sheet	0.71
		Perforated Sheet	0.73
2	Short Cartridge	Non-perforated Sheet	0.53
		Perforated Sheet	0.69
		Side Wall w/o discontinuity Stress	0.89
		Side Wall w/ discontinuity Stress	0.99
		Connecting Pipes	0.06
3	Dummy Cartridge	Mid Point	0.5
4	Support Structure	Strut S15	0.56
		Strut S13	0.78
		Sealing Pipe	0.06
		Sealing Plates	0.97
		Upper Front Supports	0.76
		Upper Rear Supports	0.78
		Strut Head 1	1.00 (Note 1)
		Strut Head 2	0.6
		Cartridge Retaining Pin	0.71
		Cartridge Retaining Ear	0.45

Note 1
The maximum membrane plus bending stress is 28.62 ksi, which only slightly exceeds the allowable stress of 28.53 ksi. The acceptant criteria are based on AISC Code, which are for linear type member such as struts, beams, and simple loading on plate, where stresses are calculated based on the entire cross section of the member. Therefore, linearized stress on the critical sections of the strainer components should be performed and compared to the AISC allowable stresses. The areas, where stress exceeds the stress acceptance criteria, are very small and are concentrated only at load discontinuities, at the applied concentrated load or imposed fixed connections. Therefore, if stress linearization were performed for the critical sections, the linearized stresses would meet the allowable stresses.

Figure 3k2 – 1
ECCS Sump Strainer Arrangement



The ECCS Sump strainer design requirements ensure that it is capable of withstanding the force of full debris loading, in conjunction with all design basis conditions, without collapse or structural damage. The design requirements also ensure that it is capable of withstanding the hydrodynamic loads and inertial effects of water at full debris loading without loss of structural integrity.

EGC Response to Issue 3k3:

The trash rack is designed to protect the strainers and physically sits between the strainers and the piping inside containment; i.e., the trash rack protects the strainer from potential dynamic effects. The replacement ECCS Sump strainers at Braidwood and Byron are located in pits inside the floor slab, between the missile barrier, and the reactor shield walls. Directly above each strainer is a concrete ceiling with 3 openings, and a trash rack has been installed above the openings. The trash rack sits on the basement floor and covers both strainer pits.

To determine if the trash rack is subject to dynamic effects, a review was conducted to determine if the trash rack is within the Zone of Influence (ZOI) of any postulated high energy line breaks (HELB). The Braidwood and Byron UFSAR was reviewed to determine the postulated pipe breaks inside containment which may impact the trash rack. These breaks are shown on Figures 3.6-25 to 3.6-99 of the UFSAR.

The trash rack lies directly below Reactor Coolant System (RCS) Loops 3 and 4. However, as discussed in the UFSAR, the Leak-Before-Break (LBB) approach (a mechanistic fracture mechanics methodology) has been applied to the primary loop piping at Braidwood and Byron Stations. Therefore, dynamic effects associated with postulated breaks on the primary loop piping are no longer considered in the design basis.

However, dynamic effects from breaks in non-primary loop piping within containment are considered. The remaining high-energy lines inside containment either branch off the primary loop piping, the pressurizer or the steam generators. This piping includes chemical and volume control, feedwater, main steam, reactor coolant, pressurizer spray and safety injection. In determining which breaks may be close enough to the trash rack for the effects of the break to impinge on the trash rack, the ZOI for each high-energy line was calculated. Secondary side breaks were not considered since ECCS recirculation flow is not required for secondary side breaks. Also, breaks outside the missile barrier wall were not considered since the wall is solid concrete and would protect the trash rack from any breaks outside the wall.

The Braidwood and Byron UFSAR states that the fluid discharge forces that result from a break are calculated using a methodology based on the simplified methods described in ANSI 58.2, "Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture." Appendix D5 of ANSI 58.2 states that jet impingement loads and pressure distribution may be evaluated using the "two-phase jet load model" described in NUREG/CR-2913, "Two-Phase Jet Loads." The Byron Safety Evaluation Report (NUREG-0876, Supplement 6) states NRC acceptance of the use of a ten-pipe diameter limit beyond which components are considered to be undamaged. Therefore the ZOI, calculated for each piping size, is based on 10D, where D is the inner diameter of the pipe (although the outer diameter was conservatively used in the analysis).

For almost all postulated breaks in the UFSAR, the trash rack lies outside the break ZOI. However, two postulated pipe breaks in the reactor coolant pressurizer piping are within 10D of the trash rack. However, these pipes carry high pressure subcooled fluid and, per NUREG/CR-2913, the pressure loading at 5D for these postulated pipe breaks is essentially 0 psi. Since these postulated breaks are more than 5D from the trash rack, a postulated pipe break in these pipes will not subject the trash rack to significant dynamic effects.

Therefore, based on the analysis outlined above, dynamic effects from breaks considered for GSI-191 in the vicinity of the trash rack (e.g., breaks in the RCS piping) are not considered in the structural analysis/design of the trash rack. The trash rack is also outside the ZOI for all applicable design basis HELBs inside containment. Therefore, dynamic effects due to design basis breaks are not considered in the structural analysis/design of the trash rack.

Note, however, that the trash rack structure is designed to withstand hydrodynamic, hydrostatic, impact, dead weight and seismic loads.

The trash rack is designed to withstand the hydraulic drag load for each surface caused by flowing water in the post-LOCA ECCS Sump. The trash rack is conservatively considered to be completely blocked by debris/foreign material when determining the drag loads on the sides, while only skin friction and form drag is considered for the top surface of the trash rack. The trash rack is also designed to withstand the hydrostatic loads on each surface due to either trash rack blockage preventing through-flow or a pressure differential across the trash rack caused by water flowing through the openings.

The trash rack is also designed to withstand the impact load due to an intact section of RMI from the RCS cold leg above the trash rack falling onto the top of the trash rack or onto the horizontal debris retainer. In addition to the impact load due to falling RMI, the trash rack is also designed for the dead weight load of the RMI which could fall onto the trash rack or onto the horizontal debris retainer. The dead weight of the trash rack grating and framing is also considered in the design of the trash rack. Seismic loads, including hydrodynamic mass and sloshing, were also accounted for in the design of the trash rack.

The following design assumptions are part of the ECCS Sump strainer design.

- For the stress analysis no hydrodynamic loads or masses has been considered.
- The total amount of debris distributed on the strainer structure is assumed to be 2205 pounds.
- Minimum ECCS Sump water temperature during recirculation 70°F
- Maximum ECCS Sump water temperature during recirculation 260°F
- Maximum containment air temperature 333°F
- The maximum pressure difference across the strainers used in the static analysis is based on the allowable head loss at 200°F. This pressure difference is converted based on the viscosity change to the minimum ECCS Sump water temperature of 70°F.
- Allowable head loss at 200°F is 5 ft
- Maximum head loss is 15.54 ft
- Maximum pressure difference is 6.723 psi

Only uniform debris loading is calculated. The pressure difference will always be the same even though the strainer has an uneven debris loading. There are only very small pressure losses within the strainer or within the ECCS Sump. Therefore, the pressure within the strainer and the pressure within the ECCS Sump are uniformly distributed, so the pressure differential is always the same.

Loads considered include the weight of the strainer (including its support structure) for a combined weight of 10,053 lbs. As stated above, the weight of debris on the strainer structure is 2,205 lbs.

The following table shows the event combinations that were considered.

Table 3k3 – 1
Load Combinations

Loading Condition	Temperature °F	Load Combination	Loading Category
3	120°F	D	Normal
5		D + E	Severe Environmental
8		D + E'	Extreme Environmental
11	70 - 260°F	D + E + Pa	Abnormal/Severe Environmental
12		D + E' + Pa	Abnormal/Extreme Environmental

Loads:
D - Weight of strainers, supporting structure, canals
Pa - Pressure difference across strainers 6.723 psi
E - OBE
E' - SSE

EGC Response to Issue 3k4:

The Braidwood and Byron 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.*

EGC Response to Issue 3l1:

The break locations are detailed in the Response to NRC Issue 3a and are identified as S1 through S4. Each break is located in the same non-compartmentalized region as the sumps, between the reactor shield wall and the missile barrier wall. The elevations for the break locations range from 386' to 393'. The sumps are located beneath floor elevation 377'. Each break location will spill directly onto the floor at 377'. As 377' is non-compartmentalized, the spill will spread and rise across the entire floor area, including the openings above the sumps. There is equipment and equipment supports in this area, but there are no choke points where water can be blocked from access to the sumps. There are inactive volumes in the same area as the breaks and sumps, but they do not represent an encumbrance to flow as it spreads across the floor. The absence of choke points was verified via visual inspections on all four units.

CSS provides spray from rings at various elevations from 567' 0" to 593' 6". The CSS sprays provide coverage over the SG cavities, RCP cavities, pressurizer cavity, and elevation 426'. The spray covers the floor, refuel pool, and other equipment. For spray that does not fall into the refuel pool, water collects and spills down the noted cavities, stairwells, and open grating. Inside the missile barrier wall, the water falls to the active pool at 377', traversing through open areas at 401' and 390'. Outside the missile barrier wall, water falls to the active pool at 377', traversing through open areas of 401' and 412'.

There are no choke points for water traversing through the noted areas, to the active pool at 377'. This was verified via visual inspection on all four units. For spray falling into the refuel pool, water fills a trapped volume to elevation 400'-1 1/2". When reaching said elevation, water then flows between the reactor vessel and the reactor shield wall where it will return to the containment floor via the incore instrumentation tunnel. The trapped volume in the refuel cavity is 6,623 ft^3, which is also incorporated into the minimum containment flood level calculation.

The water in the refuel cavity reaches the level where it drains down shortly after CSS switchover to recirculation. The opening between the reactor vessel and reactor shield wall provides a flow area of approximately 10 ft^2. This opening remains unclogged and free to flow for the following reasons. The blowdown pathway for debris to get into the refuel cavity area is to traverse from the break location upward through one of the RCP, pressurizer, or SG cavities. Each of these areas has numerous concrete and steel grating platforms which act as barriers to debris being projected upwards. The size of debris that could be projected toward the containment dome and potentially wash down into the refuel pool is limited by the grating opening dimensions. It is highly unlikely that any debris that could reach the refuel cavity would be large enough to clog the area between the reactor vessel and the reactor shield wall. Thus, once water reaches the required height in the refuel cavity, there will always be drainage available from the refueling cavity to the ECCS Sump pool.

<u>EGC Response to Issue 3I2:</u>

Visual inspections were performed on each unit to identify potential choke points for water flowing to the sumps. No choke points were identified and no mitigation actions were required.

In order to assure future plant modifications do not unknowingly create a choke point that would interfere with flow, the EGC design procedure was revised. This revision creates a review point in the Design Attributes Summary to determine if any modifications may potentially create such a choke point.

<u>EGC Response to Issue 3I3:</u>

At the base of the trash rack around each ECCS Sump is a lip approximately 2" high. This lip exists to prevent online, small scale leakage from draining into the recirculation sumps instead of the leakage detection sumps. This lip will have no impact on available water. Following a LBLOCA, the minimum available flood elevation at any point after the onset of recirculation is 9.2". The minimum flood level following SBLOCA was calculated for a range of cases with the existence of a 2" curb around the sumps. The cases covered line break sizes above and below 2", and determined minimum flood level for time after ECCS and CSS pump switchover. For break sizes less than 2", SI accumulators are not credited, conservatively minimizing flood level. This flood level has been evaluated for the applicable cases and adequate flow rates are maintained. Thus, the presence of a 2" curb around the sumps does not present an adverse impact on water holdup.

<u>EGC Response to Issue 3I4:</u>

See EGC Response to Issue 3I1 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.

3m1. 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.

3m2. 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.

3m3. 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.

3m4. Provide a summary and conclusions of downstream evaluations.

3m5. Provide a summary of design or operational changes made as a result of downstream evaluations.

EGC Response to Issues 3m1, 3m2, 3m3, and 3m4:

As part of the resolution for GSI-191, new ECCS Sump screens were installed in the Braidwood and Byron. These screens have round holes with nominal diameters of 1/12" (2.1 mm).

The susceptibility of the ECCS equipment required to pass debris laden fluid during the recirculation phase after a postulated accident to blockage was evaluated and it was determined that the ECCS equipment that would be in the post-accident recirculation path and reviewed the dimensions of close-tolerances in this ECCS equipment against the acceptance criteria of 1.1 and 2 times the nominal screen hole size. The gaps in the bushings and wear rings of the ECCS pumps were determined to have clearances less than 1.1 times the nominal screen hole size. Decreases in flow through the pump gaps would enhance the performance of the pumps so that flow decrease due to blockage is not a concern. Blockage leading to packing wear was evaluated as described below. Blockage of the fuel is addressed further below in the Response to Issue 3n. SI throttling valves and system instrumentation root valves were determined to have a minimum opening of between 1.1 and 2 times the nominal screen openings. The ECCS system throttle valves (equipment tag numbers SI8810, SI8816 and SI8822) were modified and the prototypes of these valves were tested and modified to insure that blockage with debris or wear would not alter the valves' flow coefficients outside of the tolerances allowed in the integrated ECCS system hydraulic calculation. The EGC evaluation primarily addressed component wear; however, it also included instrument lines, relief valves, and piston check valves for the potential for blockage due to debris. Blockage of these components will not prevent the ECCS systems from performing their required functions.

The methods of WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1, were used with interpretations of the November 2007 draft of the NRC Safety Evaluation to the WCAP and with interpretations described during the September 2007 training teleconference. EGC used some more detailed methods where additional quantification was required. Noteworthy differences between EGC methodology and WCAP-16406-P are described below.

Section 5 of WCAP-16406-P describes a methodology for calculating debris depletion over time. The WCAP also provides values of depletion coefficients by way of example. The WCAP does not provide specific depletion coefficients. Based on flow rates, volumes, and settling velocities at Braidwood and Byron, plant specific depletion coefficients were calculated. These depletion coefficients also credited filtration of particulates as well as fibers on the ECCS Sump screen where such filtration is supported by plant specific testing.

WCAP-16406-P provides information on size distribution and settling fraction of coatings. It states that qualified coatings fail as 10-micron particles. This is conservative for pressure drop calculations, but not for downstream wear calculations. The Braidwood and Byron specific evaluation used a larger size particle based on vendor information about size of pigments in the coatings; this results in more calculated wear and is conservative. WCAP-16406-P assumes that unqualified coatings larger than 100 microns will settle. The NRC has questioned the "Stoke's Law" models used in such evaluations during past GSI-191 audits. The Braidwood and Byron calculation uses an empirical correlation for friction factor and benchmarks the resulting settling size against NRC-sponsored settling tests. Because the paint chips were all assumed to settle with the widest cross section perpendicular to the direction of settling, the calculation showed a larger settling size for a given paint chip and settling velocity. This results in a conservative, benchmarked, plant-specific settling size for particulates.

A pump curve after wear was calculated for each type Braidwood and Byron ECCS pump rather than utilizing WCAP Figure 8.1-3. The curve in the WCAP is based on a single stage pump with a particular specific speed and does not bound the calculated wear effect for multi-stage high head, low flow pumps likes the High Pressure Safety Injection and charging pumps. The more conservative method was used in EGC calculations.

WCAP-16406-P, Revision 1, Appendix O, Section 2.3, recommends an assumed friction factor of 0.01 to maximize wear. During the performance of the calculation it was found that the rate of wear, measured as gap increase, would be maximum when the combination of parameters, friction factor times bearing length divided by clearance, was set equal to 2/3. Since this can be demonstrated mathematically it is no longer necessary to make an assumption about the friction factor in order to maximize the wear.

WCAP-16406-P does not explicitly address seal leakage within a licensing framework. The recommendation to change the secondary bushings from carbon (usually packing in contact with the shaft) to a metallic bushing which requires running clearance does not resolve leakage concerns if the pump seals are assumed to be a common mode failure. There has been no demonstration that the pump seals would fail during a postulated LOCA. The forty-hour testing referenced in Section 8.1.3 of WCAP-16406-P showed that the seals did not fail when tested. Mechanical pump seals at Braidwood and Byron were not considered to fail as a result of the downstream debris after a postulated LOCA. Such seals would still be subject to a postulated random failure of the pressure boundary as a moderate or high energy line break. Therefore, in accordance with the design for leakage for components in safeguard systems (UFSAR Section 6.3.2.5), EGC calculated the leakage rate through the pump seals one-half hour (assumed isolation time) after a postulated primary seal failure. This calculation included the affects of wear on the components in the seals that would remain intact after a primary seal failure.

Rounding the inlet to an orifice in conjunction with increasing the orifice diameter decreases the flow resistance more than just increasing the diameter. In order to account for the effects of rounding the inlet of an orifice by debris, Section 8.4 of WCAP-16406-P recommended a formula taken from the first edition of Idelchik's "Handbook of Hydraulic Resistance." The first edition, translated from Russian in the 1960's has been updated and the corresponding formula from the third edition of Idelchik's "Handbook of Hydraulic Resistance" was used.

Those ECCS components and systems that are required to operate and pass debris laden fluid during the recirculation phase of recovery from a postulated LOCA have been identified. These ECCS components have been evaluated for blockage and wear from debris that would pass through the new containment sumps screens. The ECCS equipment at Braidwood and Byron would remain capable of passing sufficient flow to the reactor to adequately cool the core during the recirculation phase of a postulated LOCA.

<u>EGC Response to Issue 3m5:</u>

The design changes described below have already been installed in Braidwood, Unit 1 and Byron, Unit 2. The same changes will be installed on the remaining two units in refueling outages in Spring 2008. Permission to install these design changes after December 31, 2007, was granted by the NRC as described in the EGC Response to Issue 2 provided above.

Design analysis identified the Safety Injection throttle valves to be susceptible to blockage during the Cold Leg and Hot Leg Recirculation Phase of ECCS operation following a LOCA. The specific components are:

SI8810A-D	Charging (CV) Pumps discharge to the RCS Cold Legs
SI8816A-D	Safety Injection (SI) Pump discharge to the RCS Hot Legs
SI8822A-D	Safety Injection (SI) Pump discharge to the RCS Cold Legs

To eliminate the blockage, each valve was modified[4]. The modification for each valve incorporates a new bonnet, stem, trim assembly, manual operator and locking device. These changes to the valves eliminate the need for the orifices that are located just downstream of each valve. As part of the scope of this modification, the orifice plates (equipment tag numbers SI04MA-D, SI05MA-D, and SI06MA-D) are replaced with a new filler plate with a hole drilled to match the inside diameter of the surrounding pipe, thus eliminating the orifice restrictions. This modification installed a Copes-Vulcan HUSH II trim. This trim consists of an assembly of nested concentric cylinders each having a series of radially drilled holes. The orifice areas are developed by arranging the cylinders, one within the other, in an offset manner so that a series of restriction (pinch areas) and expansion areas occur in series. The total pressure is thus reduced in stages. The internal design dimensions of the trim assemblies are set to minimize blockage due to debris that passes through the ECCS Sump screens (hole size of 1/12" or 0.083").

The final design of the valves' internal components was developed based on results from extensive testing at Wyle Laboratories with debris-laden fluid. The quantity of debris was based on post-LOCA debris calculations specific to Braidwood and Byron. The level of blockage, in terms of valve flow coefficient (C_v) reduction that was found by testing was used as input into a hydraulic analysis of the ECCS post accident performance. The impact of the resulting flow rates on the accident analysis has been evaluated by Westinghouse and has been found to be acceptable. The new trim design also alleviates cavitation.

[4] The SI throttle valve modifications are complete for Braidwood Unit 1 and Byron Unit 2. As discussed in the Response to NRC Issue 2, these modification will be completed for Braidwood Unit 2 and Byron Unit 1 during their Spring 2008 refueling outages.

This activity does not impact plant operations. The modified SI throttle valves stroke positions are set during a refueling outage to pass the flow rate required by the Technical Requirements Manual (TRM) Section 2.5.c.2 and 2.5.c.3. The valves are locked in these positions. These activities are the same activities that applied to the throttle valves before the modification. A reduction of the valves' C_v due to limited valve blockage during testing has been recorded. This reduction occurs in the early stages of valve operation under debris-laden conditions. ECCS recirculation flow rates based on the observed C_v reduction have been calculated and have been evaluated by Westinghouse. The results of the Westinghouse analysis show that the calculated flow rates are adequate to maintain sufficient short term and long term core cooling.

The new design of the operator for the valve incorporates an installed connection for a padlock to lock the valves in various open positions. The new configuration provides a positive method for securing the throttled position of the valves. The new valves will provide SI and CV pump runout protection previously provided by the runout orifices. Runout protection is to be provided via flow resistance in the new valves in the throttled position.

NRC Issue 3n:

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.*

EGC Response to Issue 3n:

To demonstrate acceptable ECCS and CSS performance, chemical reactions within the coolant that could alter flow through the ECCS Sump screen or lead to deposition of material within the core were evaluated consistent with WCAP-16793, "Evaluation of Long Term Core Cooling Associated with Sump Debris Effects." A plant-specific analysis was performed using plant data for input parameters such as ECCS Sump pH, ECCS Sump temperature, containment temperature, fuel rod dimensions and pellet stack length; debris bypass testing data was used for debris types and quantities. PWROG data from OG-07-477[5] was used for relative oxide thickness and relative crud thickness. The calculation used the LOCADM code to predict the growth of fuel cladding deposits from coolant impurities after a LOCA. The calculation made conservative simplifications to the required inputs.

The following conservative modifications were made:

- Increases to the amount of insulation and debris will result in the formation of more precipitates that can be carried to the core.
- Increase to the duration of ECCS Sump recirculation will result in a larger amount of precipitate deposition on the fuel.

No exceptions were taken from the WCAP-16793 methodology. The maximum temperature of the fuel cladding after the onset of recirculation was 605.3°F; this is significantly less than the acceptance criteria of 800°F established by WCAP-16793. LOCADM was also run with increased quantities of debris in accordance with the "bump-up factor" methodology described in OG-07-477. The "bump-up factor" had a negligible effect on both the total thickness and fuel cladding temperature.

Fuel blockage by fibrous debris was also assessed using the plant fibrous screen bypass fraction and the plant fibrous debris quantity; it was shown that the fiber bed thickness is calculated to be 0.059"; this was less than the acceptance criteria of <0.125". The maximum scale thickness predicted by LOCADM was added to the oxide thickness and crud thickness; the total thickness was significantly less than the acceptance criteria of 50 mils.

5 PWR Owners Group letter, "Responses to the NRC Request for Additional Information (RAI) on WCAP-16793-NP, 'Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid' (PA-SEE-0312)," dated October 31, 2007

NRC Issue 3o:

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).*

EGC Response to Issue 3o:

Responses to the content guidance in Enclosure 3, to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML072600372) are provided in the following subsections.

(1) d (i) *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.

EGC Response

The screen model that has been used for the Braidwood and Byron head loss testing was scaled based on a total screen surface area of 2120 ft^2. This area was obtained by reducing the total screen surface area of approximately 3020 ft^2 by the sacrificial area of 900 ft^2. Since this area is dedicated to miscellaneous debris (tags, stickers, etc.), the Braidwood and Byron design basis assumes that transport of debris results in no clean strainer area. Therefore, the simplified approach is not used for Braidwood and Byron.

(2) d (i) *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.

EGC Response

The debris quantities provided to the screen vendor for head loss testing are based on the break which results in the greatest quantity of debris detrimental to head loss at the strainer. Since Braidwood and Byron are both primarily RMI plants, there is no fiber insulation within the break ZOI for any of the breaks postulated at either unit at either station. Therefore, the most detrimental debris is latent debris (fiber and particulate) as well as qualified and unqualified coatings.

The debris load used for head loss testing used the maximum and bounding qualified and unqualified coatings debris load for all breaks and all stations. The latent debris quantity of 150 lbm that is assumed in the debris generation analysis is the same for each station. This value bounds the maximum quantity that was calculated based on plant walkdowns. Maximizing these quantities of debris leads to the greatest head loss.

RMI was also used in several head loss tests. The design basis head loss scenario is based on a fiber particulate debris bed upon which RMI is added. The RMI is not added with the fiber and particulates as that has been shown to lead to non-limiting head loss scenarios. Break selection criteria are discussed in detail in the Response to Item 3a.

The maximum calculated 30-day dissolved chemical quantities (aluminum, calcium, and silicon) for Braidwood and Byron were employed by the screen vendor for head loss testing. The maximum dissolved chemical quantity is independent of the break location since no break generated debris (e.g., fiber) contributes to the formation of chemical precipitates at Braidwood and Byron. The dissolved chemical quantities are determined in the chemical effects analysis which uses the WCAP-16530-NP, "Evaluation of Post Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," methodology. Inputs to the chemical effects analysis are described in more detail in the Response to Issue (3)d(i), below.

(3) d (i) 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.

EGC Response

The chemical effects analysis for Braidwood and Byron determined both the quantity of chemicals which are dissolved in the post-LOCA sump as well as the predicted quantity of precipitate present in the post-LOCA sump using the methodology (and spreadsheet) outlined in WCAP-16530-NP. Descriptions of the primary inputs to the chemical effects analysis are provided in the following paragraphs. Braidwood and Byron are similar, and therefore all inputs apply to all four units unless otherwise specified.

The materials in containment which are exposed to the sump pool and containment spray in the post-LOCA environment and which, when dissolved, may lead to precipitates in the post-LOCA sump pool are: latent debris, exposed aluminum metal, aluminum paint, and exposed concrete. This is consistent with the guidance in WCAP-16530-NP.

All latent debris is considered submerged. Latent debris is modeled as 85% particulate concrete and 15% fiberglass, and it releases calcium, silicon, and aluminum. The latent debris quantities are taken from a debris generation calculation. LOCA generated debris (i.e., stainless steel RMI and epoxy and inorganic zinc coatings) do not contribute to the quantity of dissolved chemicals in the post-LOCA sump pool since these debris types are not soluble, consistent with the WCAP guidance.

In the chemical effects analysis, aluminum metal is modeled as submerged or non-submerged. The submerged aluminum metal in containment has a surface area of 54.6 ft^2 and a mass of 120.6 lbm (values include 25% margin) for the chemical effects analysis. The non-submerged aluminum metal (excluding paint) in containment has a surface area of 815.9 ft^2 and a mass of 1712.7 lbm (values include 5% margin).

Aluminum paint in containment is accounted for separately from aluminum metal in the chemical effects analysis. The submerged aluminum paint in containment has a surface area of 4.4 ft^2 and a mass of 0.4 lbm (values include 25% margin). The non-submerged aluminum paint in containment has a surface area of 33.1 ft^2 and a mass of 3.3 lbm (values include 5% margin).

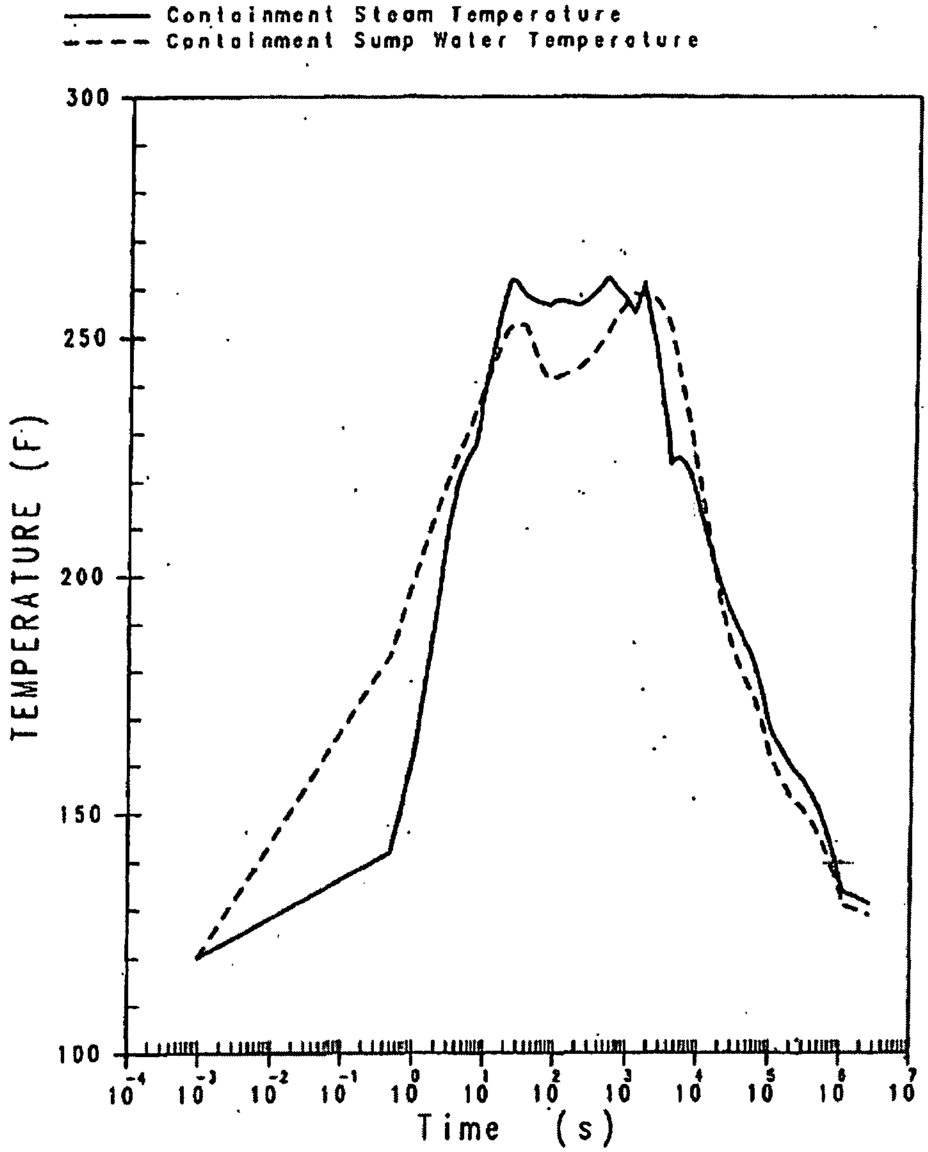
Exposed concrete is concrete which is uncoated, coated with unqualified coating, or coated with qualified coating within the break ZOI. This concrete is subject to dissolution in the post-LOCA environment. The total quantity of exposed concrete in containment is 49,381 ft^2, of which 3755 ft^2 is submerged and 45,626 ft^2 is non-submerged.

The quantity of debris, aluminum, and concrete which dissolves is dependent upon the characteristics of both the post-LOCA sump pool and the containment spray. The sump pool properties are used to determine dissolution of submerged materials and the spray properties are used to determine dissolution of non-submerged materials. The properties of the sump pool and spray which are most important are: the sump pool volume, the sump water and containment atmosphere temperature profiles, the sump and spray pH profiles, and the spray duration during the injection phase.

The maximum sump pool volume is conservatively used in the chemical effects analysis since it results in the greatest quantity of dissolved material since the material dissolution rate is dependent on the concentration of material already dissolved in the sump pool per the WCAP methodology (i.e., more material dissolves when the material concentration in the sump pool is lower). The maximum sump pool volume is determined by calculation. The chemical effects analysis uses a sump pool concentration of 2500 ppm as boron.

The sump water and the containment atmosphere temperature profiles are taken from the Braidwood and Byron UFSAR. The analyses in the UFSAR are performed using assumptions which maximize the temperature response to design-basis mass and energy release events. The sump water temperature response in all LOCA scenarios documented in UFSAR Figures was compared and the most limiting (highest temperature) scenario is selected for use in the chemical effects analysis. This scenario also results in the most limiting containment atmosphere temperature profile. The containment atmosphere and sump water temperature profiles are repeated below.

Figure 3o – 1
Containment Steam and ECCS Sump Water Temperatures



The buffer chemical that is used at Braidwood and Byron is sodium hydroxide (NaOH). The sump and spray pH profiles used in the chemical effects analysis are based on EGC calculations with a maximum sump pH of 9.8. This pH is applicable to both the sump and spray during the recirculation phase once the Containment Spray Additive Tank (CSAT) is emptied. Sodium hydroxide (NaOH) is introduced to the containment via the containment spray system; thus, the spray pH is higher than the sump pH prior to depletion of the CSAT. During the injection phase, the spray pH is 12.78 from 0 to 28.5 minutes and during the recirculation phase, the spray pH is 12.68 from 28.5 to 92.1 minutes (the time at which the CSAT is empty).

The sump pH is exponentially increased from the pH of borated water at 2500 ppm (i.e., a pH of 4.8) at the beginning of recirculation to a pH of 9.8 (the maximum sump pool pH) at the time when the CSAT is empty (92.1 minutes). All pH values used are maximum values to maximize the amount of material dissolution.

The event mission time also impacts the quantity of dissolved materials. The chemical effects analysis is performed using a post-LOCA mission time of 30 days in accordance with Section 2.0 of the SE. Therefore, the chemical quantities dissolved in the sump and the predicted precipitate quantities are based on a 30 day event duration. Containment spray is conservatively modeled as remaining on for 30 days post-LOCA which maximizes dissolution of non-submerged materials.

(4) d (i) Approach to Determine Chemical Source Term:
Licensees should identify the vendor who performed plant-specific chemical effects testing.

EGC Response

CCI performed the plant specific chemical effects tests for Braidwood and Byron.

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

EGC Response

Braidwood and Byron performed walkdowns to evaluate degraded coatings and latent debris quantities. Evaluation of qualified and unqualified coatings was performed by inspection of plant documentation including drawings and specifications. Evaluation of debris generation and debris transport was done in calculations. Evaluation of the Chemical effects on these materials by the post-LOCA containment environment followed WCAP-16530-NP methods.

(7) d (i) WCAP Base Model:
For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart, 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.

EGC Response

Other than the changes mentioned below, no other changes to the WCAP base model spreadsheet were made in the Braidwood and Byron chemical effects analysis. Also, no plant-specific refinements were incorporated into the WCAP base model spreadsheet.

The WCAP-16530-NP base model spreadsheet was originally issued in February 2006, along with the WCAP. Following the initial issuance, errors were discovered in the spreadsheet as described in Letter WOG-06-102[6] and a revised spreadsheet was issued on March 17, 2006, via Letter WOG-06-103[7]. Additional errors in the spreadsheet were discovered and were described in Letter OG-06-232[8]. These errors were corrected, and a revised spreadsheet was issued on August 7, 2006, via Letter OG-06-255[9]. Following this issuance of the spreadsheet, one additional error in the spreadsheet was discovered as described in Letter OG-06-273[10]; however, no revision to the WCAP spreadsheet was issued.

The spreadsheet used in Braidwood and Byron calculations is based on that issued in Letter OG-06-255; however, the spreadsheet was modified to address the error described in Letter OG-06-273. The error correction involved changing a cell reference in several worksheets as is described in Letter OG-06-273. Letter OG-06-273 states that this error only impacts plants which use Tri-Sodium Phosphate (TSP) for a buffer; therefore, since Braidwood and Byron utilize a sodium hydroxide buffer, this error and its associated correction do not impact the Braidwood and Byron results. The Braidwood and Byron results therefore meet the methods of the WCAP spreadsheet as revised by Letter OG-06-273.

In addition, sheets were added to the WCAP-16530-NP spreadsheet to explicitly address aluminum paint and particulate concrete separately from aluminum metal and exposed concrete. These sheets were added since the WCAP-16530-NP spreadsheet modeled the dissolution of aluminum metal and exposed concrete as a function of surface area, not thickness. Therefore, dissolution of aluminum metal and exposed concrete continues throughout the duration of the event based on the implicit assumption that there is an unlimited quantity of each material.

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6 "Distribution of Errata to WCAP-16530-NP, "Method for Evaluating Post-Accident Chemical Effects in Containment Sump Fluids" (PA-SEE-0275)," dated March 17, 2006
7 "Distribution of WCAP-16530-NP, " Method for Evaluating Post-Accident Chemical Effects in Containment Sump Fluids" (PA-SEE-0275)," dated March 17, 2006
8 "PWR Owners Group Letter Regarding Additional Error Corrections to WCAP-16530-NP (PA-SEE-0275)," dated June 17, 2006
9 "PWR Owners Group Letter Releasing Revised Chemical Model Spreadsheet From WCAP-16530-NP (PA-SEE-0275)," dated August 7, 2006
10 "PWR Owners Group Method Description of Error Discovered August 16, 2006 in Revised Chemical Model Spreadsheet (PA-SEE-0275)," dated August 28, 2006

Given the limited thickness and quantity of aluminum paint and limited mass of particulate concrete, the assumption of indefinite dissolution was not appropriate for these two materials. Therefore, separate sheets were added such that dissolution of aluminum paint and particulate concrete continued only to the point at which all aluminum paint and particulate concrete was dissolved.

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

EGC Response

The maximum quantities of dissolved chemicals in the post-LOCA sump are determined in a Braidwood and Byron calculation. The dissolved chemical quantities are conservatively lower than the chemical quantities tested during head loss testing performed by the screen vendor, CCI. Both values are presented in the table below. The values presented in the table below are the quantities of chemicals which dissolve in the post-LOCA sump over 30 days following a LOCA.

Table 3o – 1
Dissolved Chemical Quantities

Chemical	Dissolved Quantity Calculated in Chemical Effects Analysis	Dissolved Quantity Used as Basis for CCI Head Loss Tests
Aluminum	137.3 kg as Al	138.0 kg as Al
Silica	13.2 kg as SiO_2	14.9 kg as SiO_2
Calcium	7.5 kg as Ca	21.7 kg as Ca
Boron	2,500 ppm as B	2,500 ppm as B

In addition to the dissolved chemical quantities, the chemical effects analysis also predicts the quantity of precipitate which will form over 30 days following a LOCA due to the dissolved chemicals. These quantities are provided in the table below. These quantities are not used by the screen vendor.

Table 3o – 2
Chemical Precipitate Mass

Precipitate	Mass of Precipitate
Sodium Aluminum Silicate, $NaAlSi_3O_8$	19.2 kg
Aluminum Oxyhydroxide, AlOOH	300 kg
Calcium Phosphate, $Ca_3(PO_4)_2$	0.0 kg

(8) c. (i) *WCAP Refinements:*
State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

EGC Response

The Braidwood and Byron chemical effects analysis calculations do not utilize any of the refinements described in WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model."

(9) d (i) 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.

EGC Response

The Braidwood and Byron chemical effects analysis calculations do not utilize any of the refinements described in WCAP-16785-NP.

(9) d (ii) Solubility of Phosphates, Silicates and Al Alloys:
For crediting inhibition of aluminium 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 aluminium passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminium that is sprayed is assumed to be passivated.

EGC Response

The Braidwood and Byron chemical effects analysis calculations do not utilize any of the refinements described in WCAP-16785-NP. Specifically, the analysis does not model aluminum passivation.

(9) d (iii) 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.

EGC Response

The Braidwood and Byron chemical effects analysis calculations do not utilize any of the refinements described in WCAP-16785-NP. Specifically, the analysis does not credit solubility of phosphates, silicates, or aluminum alloys.

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

EGC Response

The Braidwood and Byron chemical effects analysis calculations do not utilize any of the refinements described in WCAP-16785-NP. The type and amount of predicted plant precipitates based on WCAP-16530-NP analysis are provided in the Response to Issue (7) d (ii).

(10) <u>Precipitate Generation:</u>
State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.

<u>EGC Response</u>

Precipitates are formed in the flowing test loop.

(11) d (i) <u>Chemical Injection into the Loop:</u>
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.

<u>EGC Response</u>

The volumetric settling rates shown below in Table 3o - 3 are based on a 100 ml sample size and a graduated cylinder sample height of 188 mm for 100 ml of sample.

Table 3o – 3
Precipitate Settling Rates

Name of sample	Lab Test De-Ionized Water TSS of Solution 4	Lab Test Tap Water TSS of Solution 4
Precipitate Settling Rate (mm/hr)	21.4	35.7
Precipitate Settling Rate (ml/hr)	11.3	18.9

The precipitate concentration in the final solutions of the laboratory bench tests are 6.35 g/l (deionized water solution 4) and 7.43 g/l (tap water solution 4). Section 7.3.2 of WCAP-16530-NP recommends limiting the concentration of aluminum oxyhydroxide precipitate to a maximum of 11 g/l to achieve prototypical settling behavior. Therefore the precipitate concentrations are within the limit of WCAP-16530-NP.

(11) d (ii) <u>Chemical Injection into the Loop:</u>
For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminium), the percentage that precipitates, and the percentage that remains dissolved during testing.

<u>EGC Response</u>

Two thousand one hundred ppm of aluminum was injected with 41 ppm remaining at the conclusion of the test. Four hundred and eighty ppm of calcium was injected with less than 5 ppm remaining in solution at the conclusion of the test. Two hundred and twenty ppm of silica was injected with less than 2.5 ppm remaining in solution at the conclusion of the design basis test (i.e., test number 5).

(11) d (iii) 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 percent 140 percent).

EGC Response

Testing was performed at the following precipitate levels: 40%, 70%, 100%, 120% and 140%. The test results from the 100% chemical case were used in recorded for the 120% and 140 % chemical precipitates case is minimal and can be absorbed by existing margins in the head loss analysis.

(12) d (i) Pre-Mix in Tank:
Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530.

EGC Response

One exception is taken: slightly different salts are used to form the precipitates but the aluminum precipitates determined by the methods of WCAP-16530-NP are formed.

(13) Technical Approach to Debris Transport:
State whether near-field settlement is credited or not.

EGC Response

Near field settlement is not credited.

(14) d (i) 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.

EGC Response

Not Applicable.

(14) d (ii) 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.

EGC Response

Not Applicable.

(15) d (i) 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.

EGC Response

Very little debris settlement occurred in the MFTL testing. For the Braidwood and Byron testing, a solid plate was placed approximately 260 mm (10.23 in) away from the strainer to keep the RMI close to the strainer surface and to create a vertical flow field through the RMI. An additional solid guiding plate was added in the loop near the discharge pipe. This plate created a turbulence flow that kept the debris from settling as much as possible. The height of this wall off of the floor was adjusted in order to ensure minimal settling occurred.

Through the use of turbulent flow and vertical flow field near the surface of the strainer the debris settlement could be minimized. In the testing, much of the debris remained elevated during the entire loop operation and never settled on the strainer or floor. This was caused due to the low fiber quantity in the testing and can be seen in the test operations photos for each test. In Photo 3o - 1, it can be seen that the loop remained opaque (due to the circulation of stone flour and zinc) during the entire test cycle. As the loop was being drained the debris settled to the bottom of the loop. Even with this additional settlement during drainage, the final debris amounts that settled after testing was minimal when compared to the debris in the pockets.

Photo 3o -2 was taken after removing the test cartridges in Test #2. It can be seen that settlement on the floor of the loop was very minimal. This picture was taken facing down the loop from the cartridges and the measurement was taken at the location of the wall placed 260 mm from the cartridges. Photos 3o - 3 and 4 were taken after Test #4. In these photographs, typical settlement of the tests run with the unqualified coatings modeled as zinc dust can be observed. These photographs were taken after the tank was drained, so additional settlement had occurred from the suspended debris as previously discussed. This debris quantity is still small in comparison to the debris transported to the strainer shown in Photo 3o - 5. As can be seen in Photos 3o - 3 and 4, after draining the pool there was only approximately 4.5 cm (1.77") of settlement on the floor next to the wall in front of the strainer and between the wall and the strainer. In Photo 3o - 5, it can be seen that this settlement quantity quickly tapers off into lesser amounts as you move away from the wall obstruction. The scale for the ruler in Photos 3o – 3 and 4 is in centimeters.

Photo 3o –1
Test Loop with Suspended Debris

Photo 3o – 2
Debris Settlement in Test 2

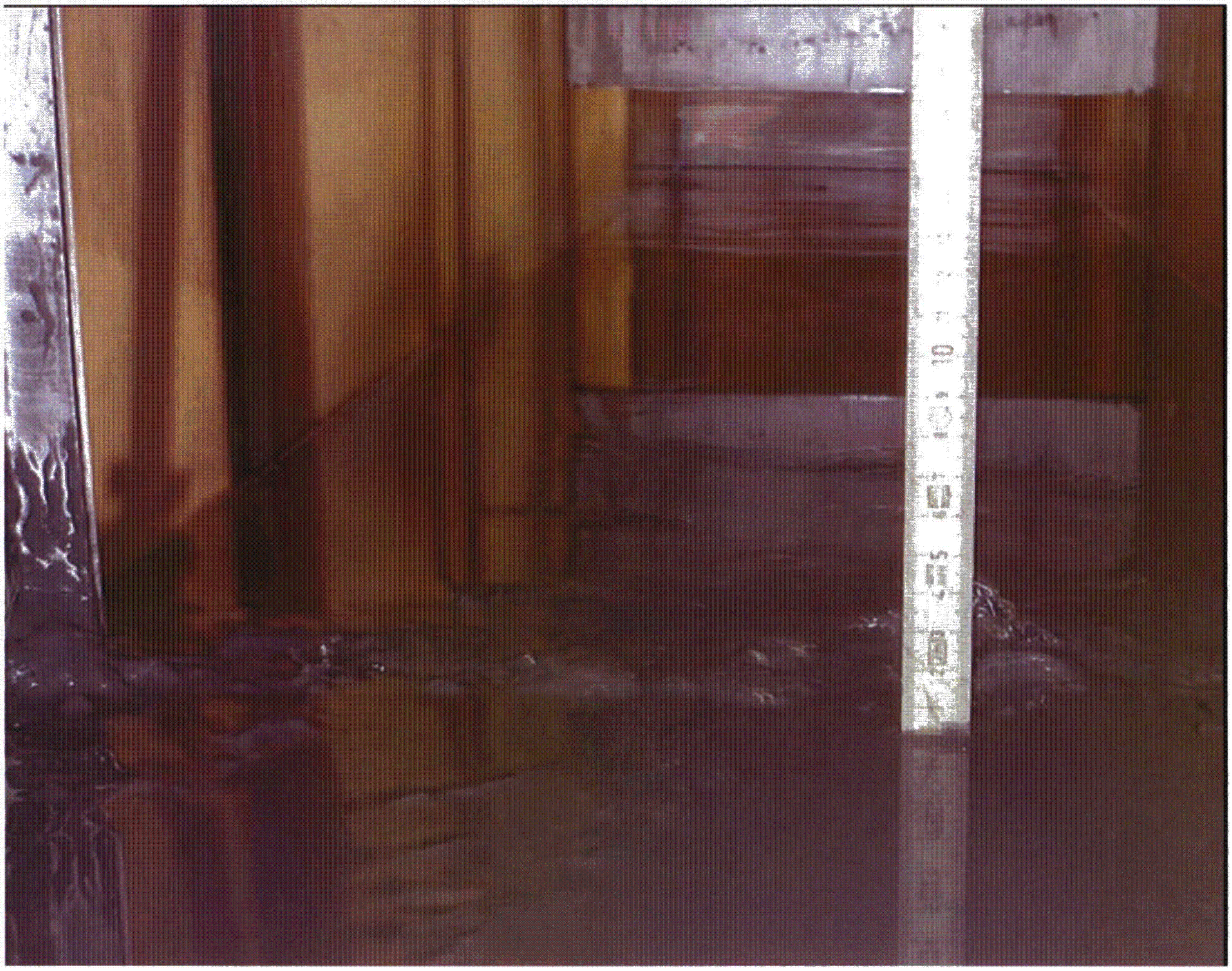


Photo 3o – 3
Debris Settlement in Test 4 after Draining

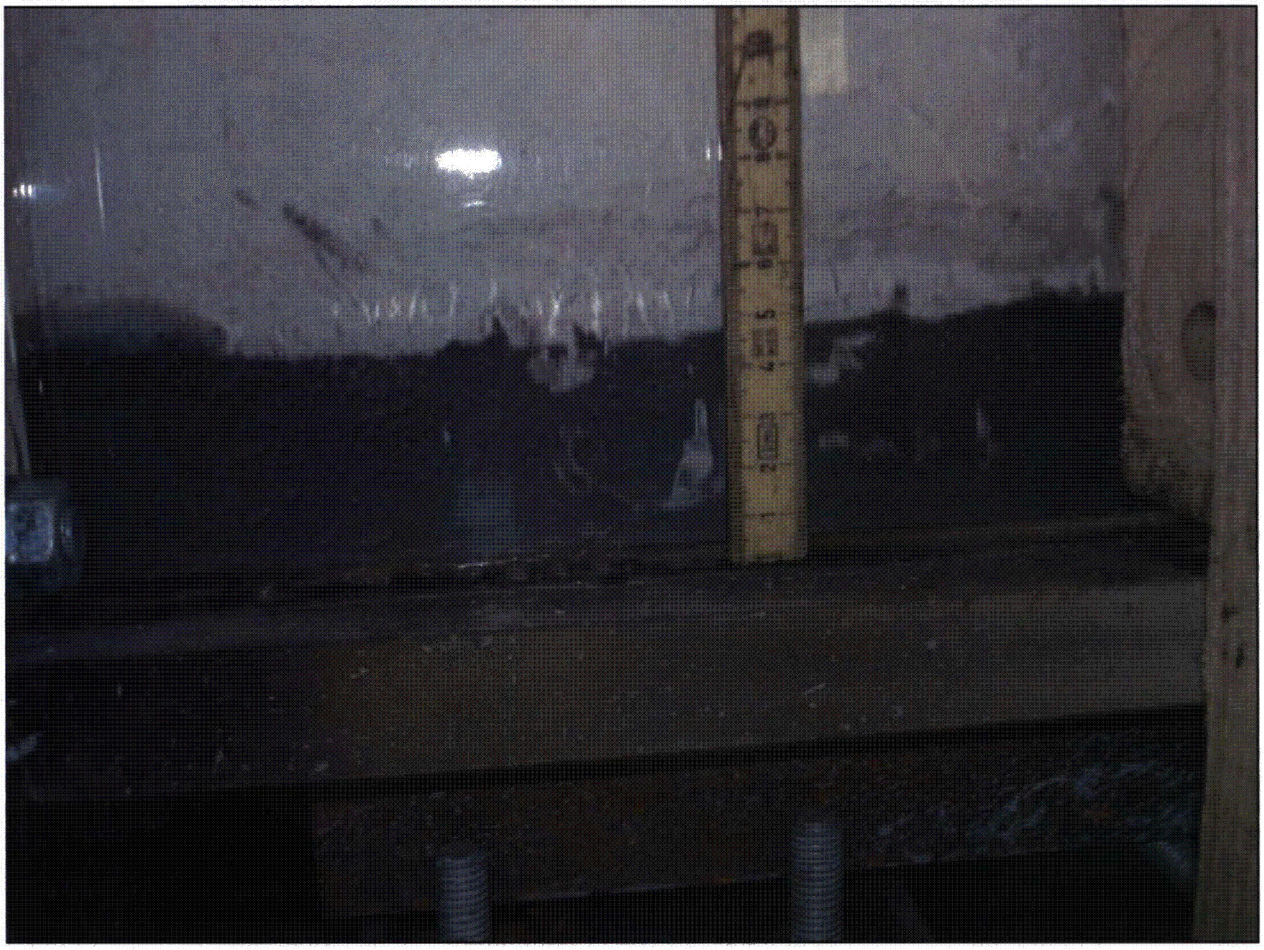


Photo 3o – 4
Debris Settlement in Test 4 after Draining

Photo 3o – 5
Test No. 4, Strainer Module after Dismounting

The observed settling is considered acceptable due to the significant margins in the tested debris quantity (epoxy specifically) that exist for Braidwood and Byron.

(15) d (ii) 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).

EGC Response

Settling rates were determined based on analyses of samples taken from the MFTL. Since precipitate settling is not a linear function, data from hour 1 to 3 were used for calculating the settling rate. The calculated settling rates are shown in the table below, based on a 100 ml sample size and a graduated cylinder sample height of 188 mm for 100 ml of sample.

Table 3o – 4
Precipitate Setting Rates

	Visible Volume of Precipitate (mm) At t (hr)											Settling Rate	
Sample	0	0.5	1	1.5	2	2.5	3	4	5	6	25	(mm/hr)	(ml/hr)
MFTL 3 100%	188	172	149	125	90	76	68	60	55	51	36	42.1	22.4
MFTL 4 100%	188	186	173	158	135	124	103	77	68	62	40	34.6	18.4
MFTL 5 100%	188	187	179	165	145	133	115	86	77	71	45	32.0	17.0

WCAP-16530-NP gives a minimum settling volume of 4.0 ml for a 10 ml sample in a 1 hr period. Since the size of the sample that was taken for the MFTL test was 100 ml, the minimum settling volume, based on the WCAP criteria, is 40 ml. All precipitate rates that were calculated are lower than 40 ml/hr. Thus, the precipitates would remain in suspension for a longer period, and this is conservative in relation to the head loss testing.

(16) d Test Termination Criteria:
Provide the test termination criteria.

EGC Response

The stabilization criteria shown in Table 3o – 5 were created based on the total head loss allowable of 2 ft.

Table 3o - 5
Test Termination Criteria

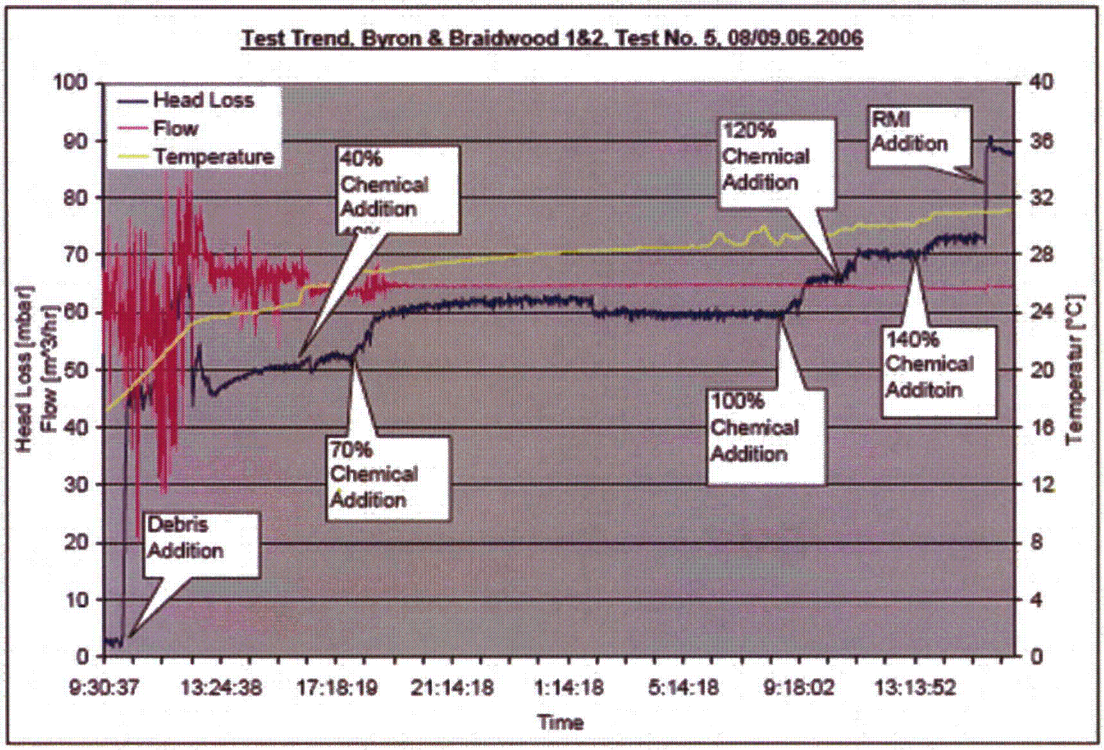
Head Loss Amount in Test	0 ft – 0.5 ft 0 cm – 15.24 cm	0.5 ft – 1 ft 15.24 cm – 30.48 cm	1 ft or Greater 30.48 cm or Greater
Stabilization Criteria for Consecutive Chemical or Debris Additions	3% in 10 minutes	3% in 20 minutes	1% in 30 minutes
Termination Criteria	**The final value taken in all tests must meet the 1% in 30 minutes stabilization value for two consecutive 30 minutes periods regardless of the head loss range.**		

(17) d (i) <u>Data Analysis:</u>
Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.

<u>EGC Response</u>

The Braidwood and Byron limiting head loss was recorded for Test 5 from the MFTL chemical effects test. The limiting head loss was determined by comparing the measured head loss values after they were normalized to the same temperature (20°C). The limiting head loss curve is shown below in Figure 3o – 2.

Figure 3o – 2
Test 5 Head Loss Results



(17) d (ii) <u>Data Analysis:</u>
Licensees should explain any extrapolation methods used for data analysis.

<u>EGC Response</u>

No extrapolation methods were used for test data analysis.

(18) d <u>Integral Generation (Alion):</u>

<u>EGC Response</u>

No tests were performed by this method.

(19) c (i) Tank Scaling / Bed Formation:
Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values.

EGC Response

Not Applicable.

(19) c (ii) 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.

EGC Response

Not Applicable.

(20) c (i) 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.

EGC Response

Not Applicable.

(21) c (i) 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.

EGC Response

Not Applicable.

(21) c (ii) 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.

EGC Response

Not Applicable.

(22) d (i) 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.

EGC Response

Not Applicable.

NRC Issue 3p:

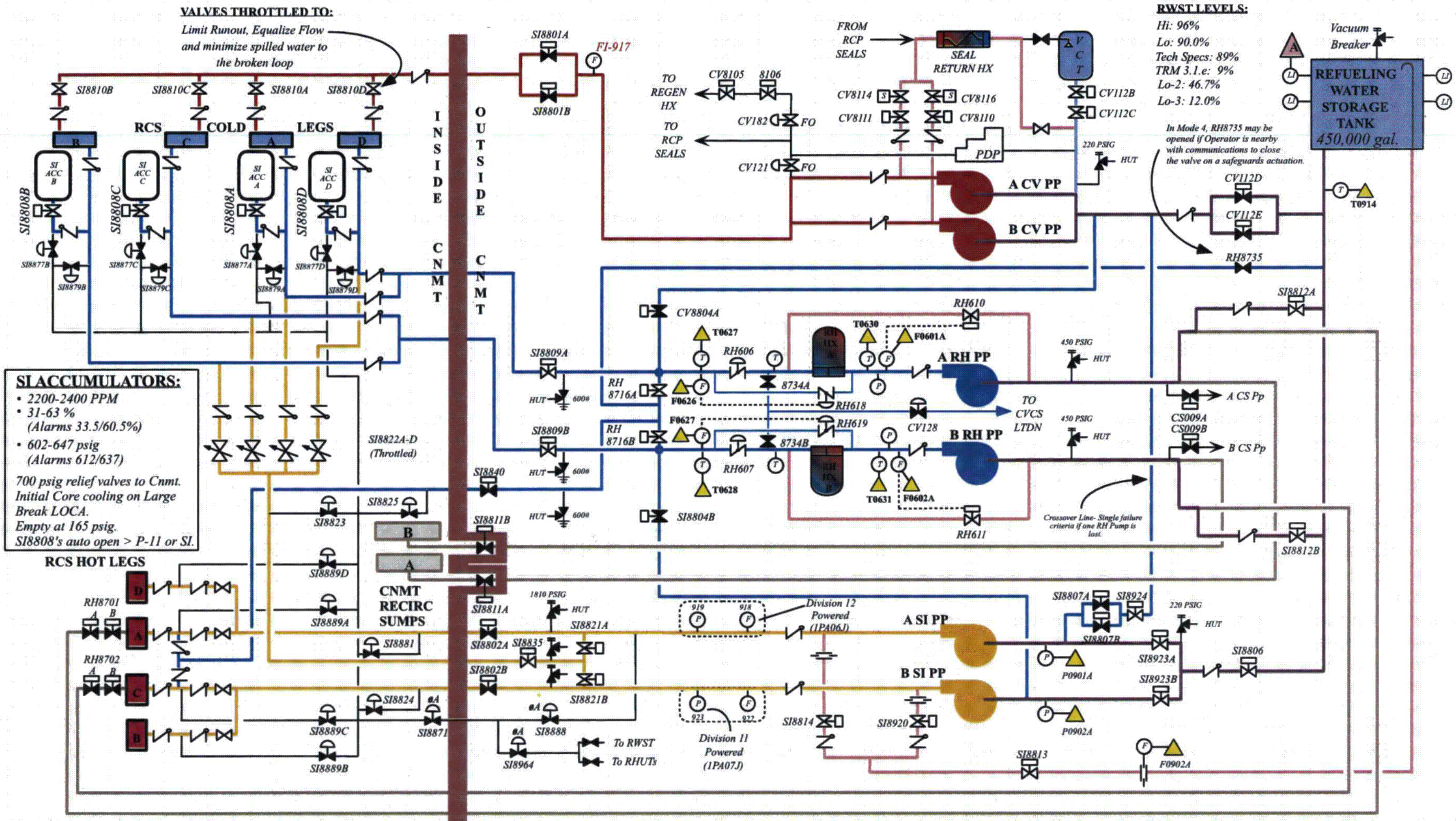
Licensing Basis
The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the sump evaluation or plant modifications. Provide the information requested in GL 04-02, "Requested Information," Item 2.(e) regarding changes to the plant 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.

EGC Response to Issue 3p:

The Braidwood and Byron licensing basis was changed in accordance with the requirements of 10 CFR 50.71. No licensing actions or exemption requests were needed to support changes to the plant licensing basis.

Braidwood Station and Byron Station
Emergency Core Cooling System
Single Line Drawings[1]

[1] Note – These are not controlled drawings.



CV PUMPS

2600 psid Shutoff
2500 psid @ 150 gpm
600 psid @ 550 gpm
381KW at 63 amps

SI PUMPS

1500 psid Shutoff
1200 psid @ 400 gpm
800 psid @ 650 gpm

RH PUMPS

200 psid Shutoff
165 psid @ 3000 gpm
125 psid @ 5000 gpm

Modes 1-3: Cannot close RH8716's (will only inject into 2 cold legs)

Mode 4: Must close 1 of the RH8716's (prevent lifting non-running RH train relief), but power must be available & capable of opening from the MCB.

CV8110/8111

Close RWST LO-2 (46.7%)
2/4 Channels
(with SI Signal)

CV8114 / 8116

Close 1448 psig and
Open 1643 psig
2/4 WR RCS Pressure (with SI Signal)
- If 2 Pressure switches are > 1643#, and 2 are < 1448 #, with an SI signal, CV8114 & CV8116 will fail Open (ETC)

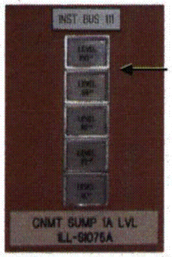
SI SIGNALS:

1. Manual (1/2 switches)
2. Low PZR Press < 1829 psig (2/4) *
3. Low Steamline Press < 640 psig (2/3 on 1/4 S/G's) *#
4. Cnmt Hi-1 > 3.4 psig (2/3)

* Manually Blocked < P-11
\# Rate Sensitive

UFSAR: 6.3

ECCS-1, ECCS SYSTEM
OCTOBER 12, REV. 9
FOR TRAINING USE ONLY



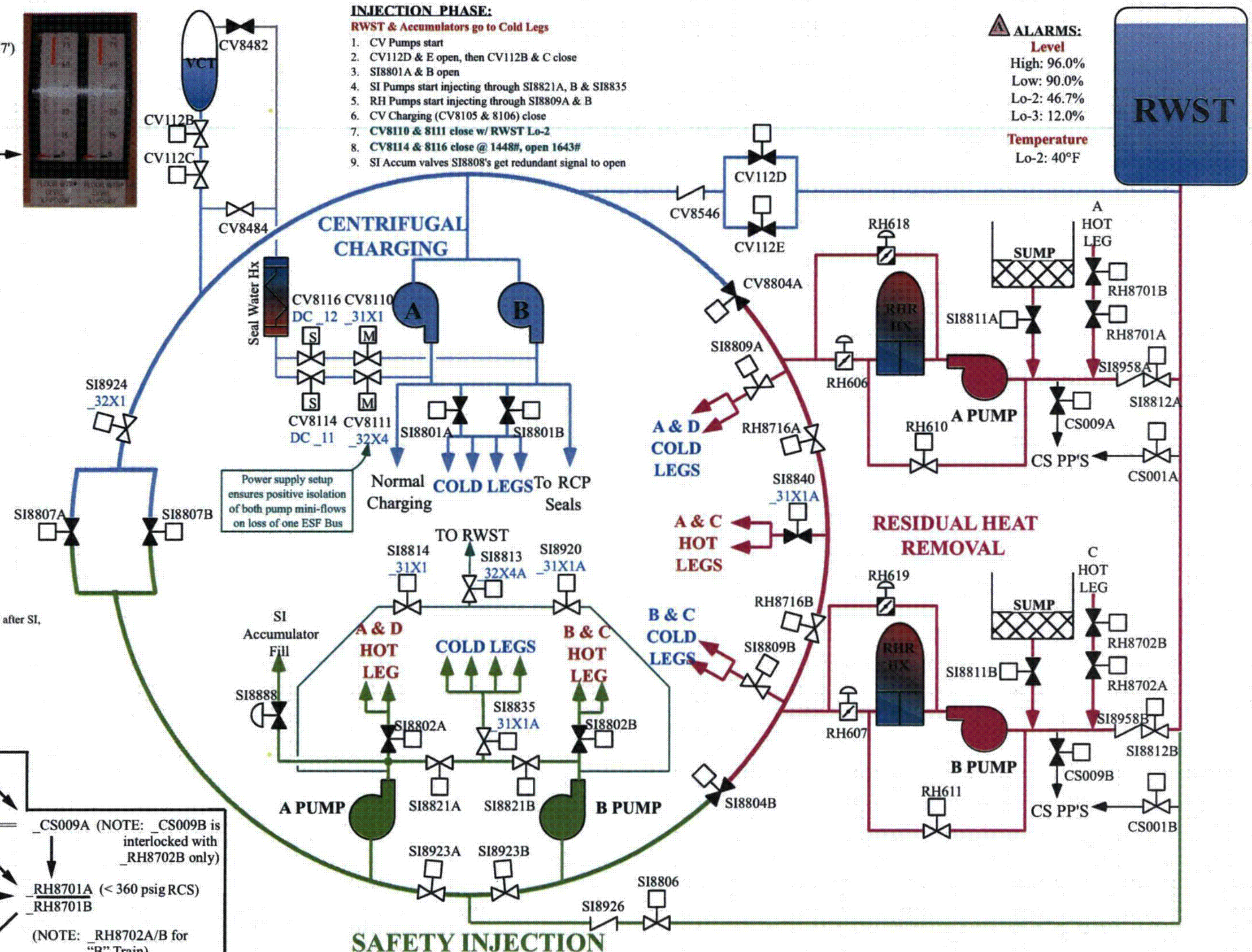
114" Cnmt Floor (377')

Status lights are no longer used in the EPs due to not being Environmentally Qualified.

INJECTION PHASE:

RWST & Accumulators go to Cold Legs

1. CV Pumps start
2. CV112D & E open, then CV112B & C close
3. SI8801A & B open
4. SI Pumps start injecting through SI8821A, B & SI8835
5. RH Pumps start injecting through SI8809A & B
6. CV Charging (CV8105 & 8106) close
7. **CV8110 & 8111 close w/ RWST Lo-2**
8. **CV8114 & 8116 close @ 1448#, open 1643#**
9. SI Accum valves SI8808's get redundant signal to open



COLD LEG RECIRCULATION (EP ES-1.3):

Need SI with RWST Lo-2 (46.7%)

1. SI8811A & B Auto open (RWST Lvl & SI)
2. Establish CC flow to RH HX's, open _CC9412A & B
3. Check adequate floor water level, close SI8812A & B
4. **All pumps discharge to cold legs**
   - A. CV8110, 8111, 8114 & 8116 closed
   - B. SI8813, 8814 & 8920 (SI recircs) manually closed **(Prevents radioactive water to RWST)**
   - C. RH8716A & B (RH train xtie) Manually closed **(Prevents fault on one train starving both trains)**
   - D. SI8807A , B & 8924 (CV to SI) manually opened **(Single RH train can supply all ECCS Pumps)**
   - E. Open CV8804A & SI8804B (RH to CV & SI Pp's)
5. Reset SI signal to reposition valves
6. CV112D, E & SI8806 manually closed (Isolates all flowpaths from RWST to ECCS pumps
7. At RWST Level Lo-3 alarm: Open CS009A/B (Sump suctions), and Close CS001A/B (RWST suctions)

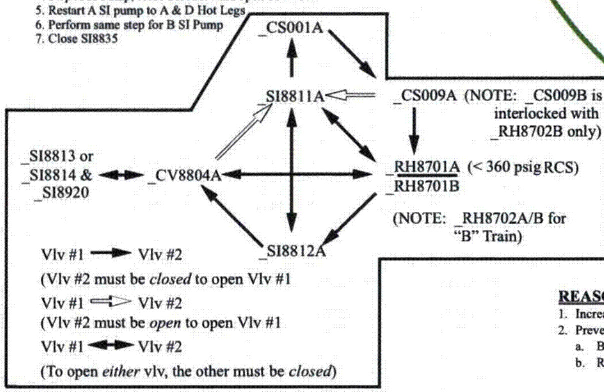
HOT LEG RECIRCULATION (EP ES-1.4):

[Between 5 hours and 50 minutes and 6 hours and 10 minutes after SI, prepare for hot leg recirc 4 hours and 50 minutes after SI]

'A' RH to A & C Hot Legs, 'B' RH to SI & CV Pp's, SI to Hot Legs, CV to Cold Legs

(May not be sure of where the break is located at)

1. Close SI8809A & B
2. Open RH8716A
3. Open SI8840 for RH to A & C Hot Legs
4. Stop A SI Pump, close SI8821A and open SI8802A
5. Restart A SI pump to A & D Hot Legs
6. Perform same step for B SI Pump
7. Close SI8835



REASONS FOR HOT LEG RECIRC:

1. Increases Core flow
2. Prevent plating out (due to boiling) which would:
   a. Block flow Channels
   b. Reduce heat transfer.

SVAG VALVES (8):

(De-energize per Tech Specs)

Modes 1-3

1. SI8806 Open
2. SI8835 Open
3. SI8813 Open
4. SI8802A, B Closed

Modes 1-4 (H.L. Injections)

1. SI8809A, B Open
2. SI8840 Closed

SVAG REASONS:

1. Misalignment of valve render both trains of ECCS inoperable.
2. Securing valves in position by removing power ensures valves can't be repositioned by active failure or inadvertent mispostioning

ECCS-2, ECCS RING
NOVEMBER 29, 2006, REV. 8
FOR TRAINING USE ONLY