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July 10, 2008

PG&E Letter DCL-08-059

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

Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82
Diablo Canyon Units 1 and 2
Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors" (Revision 1)

Reference:

1. NRC letter to PG&E, "Diablo Canyon Power Plant, Units 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,'" (TAC Nos. MC4682 and MC4683), dated February 9, 2006.
2. PG&E Letter DCL-08-002, "Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," dated February 1, 2008.

Dear Commissioners and Staff:

On September 13, 2004, the Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," to all pressurized water reactor (PWR) licensees as part of the NRC's efforts to assess the likelihood that the emergency core cooling system (ECCS) and containment spray system (CSS) pumps at domestic PWRs would experience a debris induced loss of net positive suction head (NPSH) margin during sump recirculation. GL 2004-02 requested that addressees perform an evaluation of the ECCS and CSS recirculation functions in light of the information provided in the GL, and if appropriate, take additional actions to ensure system function. Addressees were also required to submit information specified in GL 2004-02 to the NRC in accordance with Title 10 of the Code of Federal Regulations Section 50.54(f).

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Pacific Gas and Electric Company (PG&E) provided its response to GL 2004-02 by PG&E Letter DCL-05-014, dated March 4, 2005, as supplemented by PG&E Letter DCL-05-079, dated July 21, 2005, and PG&E Letter DCL-05-099, dated September 1, 2005. By letter dated February 9, 2006 (Reference 1), the NRC staff requested additional information required to complete its review of PG&E's response to GL 2004-02. PG&E's response to that request was provided in PG&E Letter DCL-08-002, dated February 1, 2008 (Reference 2). The information provided in Reference 2 is revised in the Enclosure to this letter to reflect Diablo Canyon Power Plant (DCPP) Unit 2 actions completed prior to restart from the Unit 2 Fourteenth Refueling Outage. DCPP Unit 2 is in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02. This revision also discusses recently completed bottom nozzle testing, and revises Sections 3m, Downstream Effects – Components and Systems, and 3n, Downstream Effects – Fuel and Vessel, to reflect recently completed evaluations. This Enclosure supersedes the information provided by PG&E in Reference 2, in its entirety.

PG&E makes no regulatory commitments (as defined by NEI 99-04) in this letter. This letter includes no revisions to existing regulatory commitments.

If you have any questions, or require additional information, please contact Stan Ketelsen at (805) 545-4720.

I state under penalty of perjury that the foregoing is true and correct.

Executed on July 10, 2008.

Sincerely,

James R. Becker
Site Vice President and Station Director

tcg/4231
Enclosure
cc: Diablo Distribution
cc/enc: Gary W. Butner, Acting Branch Chief, California Department of Public Health
Elmo E. Collins, Regional Administrator, NRC Region IV
Michael S. Peck, NRC Senior Resident Inspector
Alan B. Wang, Project Manager, Office of Nuclear Reactor Regulation

SUPPLEMENTAL RESPONSE TO GENERIC LETTER (GL) 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS" (REVISION 1)

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LIST OF ACRONYMS

AEC	Atomic Energy Commission
ALOOH	Aluminum Oxyhydroxide
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials (ASTM International)
BNT	(Fuel) Bottom Nozzle Test
BWR	Boiling Water Reactor
BYP	(Fiber) Bypass Test
CAD	Computer-Aided Drafting
Cal-sil	Calcium Silicate
CCP	Centrifugal Charging Pump
CFD	Computational Fluid Dynamic (analysis)
CS	Containment Spray
CSP	Containment Spray Pump
CSS	Containment Spray System
DBA	Design Basis Accident
DCL	Diablo Canyon Letter (PG&E Letter to the NRC)
DCPP	Diablo Canyon Power Plant
DE	Design Earthquake
DDE	Double Design Earthquake
ECCS	Emergency Core Cooling System
ECE	Early Chemical Effects (Test)
EOP	Emergency Operating Procedure
EPG	Emergency Planning Guide
EPR	Ethylene Propylene Rubber
EPRI	Electric Power Research Institute
ERG	Emergency Response Guidelines
FCV	Flow Control Valve
FSARU	Final Safety Analysis Report Update
FSHL	Front Sector Head Loss (test)
GDC	General Design Criteria
GET	General Employee Training
GL	Generic Letter
GSI	Generic Safety Issue
LBLOCA	Large Break Loss of Coolant Accident
LOCADM	Loss of Coolant Accident Deposition Model
LTSP	Long Term Seismic Program

LIST OF ACRONYMS
(Continued)

NAS	Sodium Aluminum Silicate
NEI	Nuclear Energy Institute
NPSH	Net Positive Suction Head
NPSHA	Net Positive Suction Head Available
PG&E	Pacific Gas and Electric Company
PSG	Post-Steam Generator (replacement debris or test)
PWR	Pressurized Water Reactor
PZR	Pressurizer
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHR	Residual Heat Removal
RMI	Reflective Metal Insulation
RPT	Repeatability (test)
RSHL	Rear Sector Head Loss (test)
RWST	Refueling Water Storage Tank
S	Sector (test)
SAT	Spray Additive Tank
SBLOCA	Small Break Loss of Coolant Accident
SE	Safety Evaluation (NRC)
SFP	Spent Fuel Pool
SG	Steam Generator
SGR	Steam Generator Replacement
SI	Safety Injection
SIP	Safety Injection Pump
SR	Silicone Rubber (cable insulation)
STP	Surveillance Test Procedure
SS	Stainless Steel
SSPC	Society for Protective Coatings (formerly Steel Structures Painting Council)
TKE	Turbulent Kinetic Energy
URG	Utility Resolution Guidance
XLPE	Cross-linked Polyethylene (cable insulation)
ZOI	Zone of Influence

1. Overall Compliance

Provide information requested in GL 2004-02 Requested Information Item 2(a) regarding compliance with regulations.

> *GL 2004-02 Requested Information Item 2(a)*
> *Confirmation that the ECCS [emergency core cooling system] and CSS [containment spray system] 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.*

Pacific Gas and Electric Company (PG&E) Response:

Diablo Canyon Power Plant (DCPP) Unit 2 is in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02. The effective date of Unit 2 compliance is April 11, 2008. DCPP Unit 1 will be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02 upon completion of the Unit 1 Fifteenth Refueling Outage (1R15), currently scheduled to start January 26, 2009.

The Applicable Regulatory Requirements section of NRC Generic Letter (GL) 2004-02 states:

> *NRC regulations in Title 10, of the Code of Federal Regulations Section 50.46, 10 CFR 50.46, require that the ECCS have the capability to provide long term cooling of the reactor core following a LOCA [loss-of-coolant accident]. That is, the ECCS must be able to remove decay heat, so that the core temperature is maintained at an acceptably low value for the extended period of time required by the long lived radioactivity remaining in the core.*
>
> *Similarly, for PWRs [pressurized-water reactors] licensed to the General Design Criteria (GDCs) in Appendix A to 10 CFR Part 50, GDC 38 provides requirements for containment heat removal systems, and GDC 41 provides requirements for containment atmosphere cleanup. Many PWR licensees credit a CSS, at least in part, with performing the safety functions to satisfy these requirements, and PWRs that are not licensed to the GDCs may similarly credit a CSS to satisfy licensing basis requirements. In addition, PWR licensees may credit a CSS with reducing the accident source term to meet the limits of 10 CFR Part 100 or 10 CFR 50.67. GDC 35 is listed in 10 CFR 50.46(d) and specifies additional ECCS requirements. PWRs that are not licensed to the GDCs typically have similar requirements in their licensing basis.*

Exceptions to the applicable regulatory requirements in GL 2004-02 for DCPP Units 1 and 2 are the following:

As stated in the DCPP Final Safety Analysis Report Update (FSARU) Chapter 3, "Design of Structures, Components, Equipment, and Systems," the DCPP units were designed to comply with the Atomic Energy Commission (now the Nuclear Regulatory Commission) General Design

Criteria for Nuclear Power Plant Construction Permits, published in July 1967. The DCPP construction permits were issued in April 1968 and December 1970 for Units 1 and 2, respectively. FSARU Appendix 3.1A lists the GDCs published as Appendix A to 10 CFR 50 in February 1971, and provides a discussion of conformance with the 1971 GDCs (DCPP Units 1 and 2 conform to the intent of the 1971 GDCs).

License Amendments 139 (Unit 1) and 139 (Unit 2) dated February 9, 2000, clarified the Bases for Technical Specification (TS) 3.6.6, "Containment Spray and Cooling Systems," to indicate that the CSS is not required to be actuated during recirculation, but may be actuated at the discretion of the Technical Support Center. If containment spray (CS) is used during recirculation, it is provided by aligning the residual heat removal (RHR) system to the spray headers.

Compliance with the Applicable Regulatory Requirements was (Unit 2) or will be (Unit 1) achieved through analysis, plant-specific testing, mechanistic evaluations, installation of new containment recirculation sump screens, plant modifications to reduce debris and debris transport to the containment recirculation sump screens, and programmatic and process changes to ensure continued compliance. The analysis methodology used for demonstrating compliance is that described in Nuclear Energy Institute (NEI) 04-07, Volume 1, "Pressurized Water Reactor Sump Performance Methodology," and NEI 04-07, Volume 2, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02," Revision 0, dated December 2004. Exceptions to the methodology in NEI 04-07 are discussed in Section 3. Compliance with the regulatory requirements is not based on the alternate evaluation methodology in NEI 04-07, Section 6.

Beginning with the plant physical improvements and proceeding through exhaustive analyses and comprehensive testing programs, DCPP is taking appropriate actions to ensure acceptable ECCS performance in the recirculation mode. We have high confidence in the integrity of these programs because of the intensive in-process quality oversight applied throughout the evolution. Selective portions of the testing and analyses have been witnessed by the NRC staff and presented for NRC review at NRC public meetings on GL 2004-02.

Specific physical improvements include:

- Installation of a new containment sump strainer assembly with approximately five times the area of the sump screens upgraded in the tenth refueling outages in 2000 and 2001, and 40 times the area of the original screens;
- Modification of the reactor cavity door to allow more debris to flow into the reactor cavity inactive sump;
- Addition of three debris interceptors to capture reflective metal insulation (RMI) and unqualified coating paint chips;
- Removal of cable tray fire stops inside the pipe break zones of influence (ZOI);
- Installation of multiple banding on approximately 1400 linear feet of calcium silicate (cal-sil) piping insulation inside the pipe break ZOIs;
- Installation of stainless steel jacketing on Temp-Mat piping insulation inside the pipe break ZOIs;
- Installation of tray covers to protect the pressurizer heater cable insulation in cable trays below the pressurizer;

- Installation of stainless steel jacketed Temp-Mat insulation on the inlet to the pressurizer safety valves.
- Removal of calcium silicate and mineral wool insulation, installation of stainless steel jacketed Temp-Mat insulation, and installation of reflective metal insulation on all four steam generators when the steam generators are replaced.

The new containment recirculation sump strainer assembly was custom engineered by General Electric (GEH-Nuclear Energy). The passive safety-related strainer assembly includes a trash rack, debris curb, and front and rear strainers and plenums. The common plenums supply flow to both trains of RHR suction piping. The strainer-perforated plate has 3/32-inch holes with a wire cloth overlay. At full flow the approach velocity is less than 0.01 feet per second. The strainer assembly is located in the containment annulus, outside the crane wall, and is not subject to pipe whip, jet impingement, or missile impact loads. The entire assembly along with welds, fasteners, and anchorage has been analyzed for limiting load combinations of dead, live, thermal, hydrodynamic, and the four DCPP design basis earthquake loads.

The following paragraphs summarize the DCPP analyses, testing, and programmatic controls that ensure that DCPP complies with the design and licensing requirements of GL 2004-02.

There are inherent conservatisms in the NEI 04-07 methodology, most notably in the assumed spherical destruction of debris from any pipe break and the expansive default ZOIs applied in the debris generation methodology. In order to minimize uncertainties in the generation and transport analyses, DCPP performed jet impingement testing, erosion testing, debris transport characteristics testing, and debris interceptor testing. As a result of this extensive testing, minimal conservatisms are required in the DCPP generation and transport analyses other than those already inherently applied in the NEI 04-07 methodology.

As there are no acceptable analytical methods available for the selection and sizing of a suitable strainer, the resolution of GL 2004-02 for DCPP was an evolution of iterations of head loss testing, fiber bypass testing, and debris mitigation. A base debris loading was obtained from the existing debris within containment. DCPP had already installed new screens in 2000. Initial head loss testing was performed to determine the performance of the installed screens. When chemical effects were introduced, the existing debris produced too great a head loss with the installed screens. The head loss tests indicated the need for either a larger screen and/or a reduction of the amount of debris that was generated and transported. As the screen size was limited due to the space constraints and fiber bypass limitations, various debris mitigation options were considered. The resulting debris loads were determined and subsequent head loss and bypass tests were performed to verify strainer performance. This iteration process was repeated, as required to obtain successful results. The ultimate resolution was the fuel grid and bottom nozzle head loss testing which confirmed the ability to maintain a coolable core on recirculation with debris-laden fluid.

The breaks that present the greatest challenge to post-accident sump performance are the breaks that generate limiting (greatest) amounts of calcium silicate and fibrous debris. All areas with a significant potential to generate significant fibrous debris (Loop 2 crossover leg, pressurizer surge line, and pressurizer loop seal lines) have been analyzed. All areas with a significant potential to generate significant calcium silicate debris (hot-leg, cold-leg, and crossover legs on all four loops, pressurizer loop seals, and RHR hot-leg recirculation line) have been analyzed.

The DCPP debris generation analysis utilizes the ZOI refinement discussed in Section 4.2.2.1.1 of NEI 04-07, Volumes 1 and 2, which allows the use of debris-specific spherical ZOIs. Using this approach, the amount of debris generated within each ZOI is calculated, and the individual contributions from each debris type are summed to arrive at a total debris source term. In certain cases, DCPP performed jet impingement testing to determine appropriate ZOIs.

The methodology used in the transport analysis is based on the NEI 04-07, Volume 1, guidance for refined analyses as modified by the refined methodologies suggested in Appendices III, IV, and VI of NEI 04-07, Volume 2. The specific effects of each of four modes of transport (blowdown, washdown, pool fill-up, and recirculation) were analyzed for each type of debris generated. The logic tree approach was then applied for each type of debris determined from the debris generation analysis.

Sump strainer head losses were determined though a combination of testing and analysis. Screen head losses were determined using a range of tests since no analytical methods are available. The testing performed was designed to assure that a conservative design basis head loss would be determined for DCPP. The head losses associated with the portion of the strainers downstream of the perforated plate screens (the strainer plenums and RHR piping entrance) were conservatively established using industry accepted analytical methods.

All debris shown to arrive at the strainer in the debris transport calculation was included in the test debris scaling (or accounted for through sacrificial area). Near field effects were not used as a basis to reduce any debris source. To minimize the possibility of settling in the test tank, debris was homogeneously mixed and maintained in suspension in the test pool using a combination of return flow from the pump and mechanical agitators.

Chemical precipitates were calculated using the methodology in WCAP-16530-NP, Revision 0, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191." DCPP has not utilized any of the additional inputs discussed in WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model." DCPP made one refinement to the WCAP-16530-NP methodology. The WCAP-16530-NP model was modified to include four inputs for plant aluminum inventory. Westinghouse has verified DCPP's proper implementation of the WCAP-16530-NP methodology including the aforementioned refinement. The chemical precipitate debris used in the test program was pre-mixed in tanks and prepared in accordance with the recommendations in WCAP-16530-NP, with revised turbid volume acceptance criteria based on DCPP test observations.

All strainer head loss tests performed by DCPP developed a thin fiber (or fiber and cal-sil) bed over a portion of the strainer. The resolution path for acceptable head loss was to ensure that the portion of the strainer without a fiber and/or cal-sil bed did not get overwhelmed by unqualified coating chips to the point that the chemicals were filtering out over the entire expanse of the coating chip beds with the intent of achieving clean screen area.

From the testing performed by DCPP, there is reasonable assurance that the fiber and cal-sil beds, and the coating chip beds on the strainer (the filtering beds), are not large enough to result in strainer failure (will not cause excessive head loss) for any of the analyzed breaks. DCPP has sufficiently tested the limiting breaks, and by properly addressing all potential debris sources (fiber, calcium silicate, unqualified coating chips, particulate, latent debris, miscellaneous debris, and chemical effects) has achieved acceptable head loss results.

DCPP has assured acceptable strainer performance through consideration of screen sizing, a number of debris removal modifications, installation of debris interceptors, and extensive strainer head loss testing. These actions have provided reasonable assurance that there will be sufficient clean area on the DCPP strainers for all breaks, and this has been demonstrated through the test program. The results of this testing demonstrated that the DCPP strainer design is capable of operating after a small-break LOCA and under full flow conditions after a large-break design basis LOCA without generating a vortex which would result in the entrainment of air into the strainers and the ECCS system. DCPP has also demonstrated (through testing) the ability to back-flush the strainer in the beyond design basis event that the strainer becomes completely obstructed by a debris bed.

For the net positive suction head (NPSH) margin calculations, no subcooling due to containment pressure was credited. The NPSH margin calculations were performed for both the full flow dual train operation and the most limiting single active failure. To ensure an adequate containment water level is available to submerge the strainer at the start of recirculation for the large-break LOCA case, the refueling water storage tank (RWST) level was increased. A License Amendment Request to revise the TSs was submitted. The NRC issued Amendment No. 199 to Facility Operating License DPR-80 and Amendment No. 200 to Facility Operating License DPR 82, for Units 1 and 2, respectively, approving the change in the RWST level on March 26, 2008.

Downstream effects evaluations of components and systems were developed to address 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. Close-tolerance subcomponents in pumps, valves, and other ECCS and CSS components were evaluated for potential plugging or excessive wear due to extended post-accident operation with debris-laden fluids. The evaluations were developed in accordance with WCAP-16406-P, Revision 1, and the accompanying NRC Safety Evaluation (SE). No exceptions were taken to the WCAP-16406-P methodology. The downstream effects evaluations show that the DCPP ECCS and CSS equipment would not fail as a result of blockage, plugging, wear, or abrasion from the effects of debris ingested through the containment sump screen during recirculation mode of the ECCS and CSS. There were no design modifications required as result of the downstream effects evaluations. There was a revision to existing procedures, and the creation of a new procedure to provide the process to detect and isolate a leak during post-LOCA recirculation.

Downstream effects evaluations of vessel blockage and fuel cladding deposits were developed to address the effects on core cooling of debris carried downstream of the containment sump and into the reactor vessel. The evaluation of vessel blockage examined the reactor vessel internals, and the core inlet and exit for possible blockage locations. The evaluation confirmed that any debris that could pass through the strainer would not challenge the limiting (smallest) clearances in the vessel. The LOCA deposition model (LOCADM) code from WCAP-16793-NP, Revision 0, was used to predict fuel cladding deposits, and to determine the clad/oxide interface temperature that occurs when coolant impurities enter the core following a LOCA. The results show that the maximum local oxidation, the core-wide oxidation, and the peak cladding temperature calculations for the traditional LOCA analyses are still valid. The assessment of fuel blockage is discussed below as part of fuel bottom nozzle testing.

In addition to strainer head loss testing, DCPP performed fiber bypass testing and fuel bottom nozzle head loss testing. The fuel bottom nozzle head loss tests were conducted using the actual fibrous debris which bypassed the strainer test article (during the fiber bypass tests), and included maximum particulate debris (it was conservatively assumed that 100 percent of the particulate debris which arrives at the strainer also arrives at the fuel bottom nozzle). The fuel bottom nozzle head loss tests also conservatively included all chemical precipitate debris (some of these precipitates would be filtered out of solution by the debris bed on the strainer). Additional design basis debris load fuel bottom nozzle head loss testing was conducted in May 2008. Portions of this testing were observed by the NRC staff (ADAMS Accession Number ML081690224).

The fuel bottom nozzle head loss results have been evaluated by Westinghouse through a comparison between the measured head loss and the available driving head for the various DCPP LOCA scenarios. The Westinghouse evaluation is an alternate assessment of fuel blockage and takes exception to the WCAP-16406-P screening evaluation method. The Westinghouse comparisons showed that sufficient driving head is available to match the head loss due to debris buildup, therefore, adequate flow will enter the core to match boil-off, and the core will remain covered. Because the core remains covered, no late heat-up occurs.

A controlled program for painting and special coatings has been in effect since the start of painting activities at DCPP in 1972. The program includes active monitoring, evaluation, and tracking of qualified and unqualified coatings in containment. A major portion of the unqualified coating systems have been LOCA/design basis accident (DBA) tested. Although the test results showed that the unqualified coatings failed into small pieces 2 inches and larger, DCPP has conservatively assumed failed chips sized small enough to be easily transported and large enough to cause strainer blockage. DCPP maintains a monitoring program of containment coatings, performed by coatings-qualified Level III Inspectors, and conforming to ANSI, EPRI and DCPP standards and procedures.

DCPP has established aggressive ongoing containment cleaning programs and foreign material exclusion programs to ensure the debris in containment is monitored and controlled within the design and tested limits of the new strainer. These oversight programs include control of new design and maintenance activities, personnel training and qualifications, inspections, and cleanup and cleanliness activities.

In conclusion, PG&E is taking the appropriate actions in response to GL 2004-02 to ensure acceptable ECCS performance in the recirculation mode. Through physical plant modifications, detailed analysis and testing DCPP has high confidence that the new strainer conforms to the requirements of GL 2004-02. Long-term programs for control and monitoring of debris ensure the strainer will continue to conform to these requirements for the life of the plant.

DCPP Unit 2 is in full compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02. The remaining corrective actions required to address the issues in GL 2004-02 for Unit 1 will be completed by the date established in the DCPP extension letters previously approved by the NRC. The following sections of this enclosure discuss the configuration of Units 1 and 2 after all corrective actions required for regulatory compliance have been completed.

2. General Description of and Schedule for Corrective Actions

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). (Note: All requests for extension should be submitted to the NRC as soon as the need becomes clear, preferably not later than October 1, 2007.)

> <u>*GL 2004-02 Requested Information Item 2(b)*</u>
> *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.*

<u>PG&E Response:</u>

DCPP Unit 2 is in full compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02.

By letters dated February 22, 2007, and March 27, 2007, for Unit 1, PG&E requested extensions of the December 31, 2007, date until completion of 1R15, scheduled to begin January 26, 2009. The NRC approved the Unit 1 extension request in letter dated April 12, 2007. Remaining corrective actions required to address the issues in GL 2004-02 will be completed prior to Unit 1 startup from 1R15.

The following administrative controls have been established:

1. Amendment No. 199 to Facility Operating License DPR-80, and Amendment No. 200 to Facility Operating License DPR-82, for Units 1 and 2, respectively, revised the TS 3.5.4 minimum contained borated water volume to reflect the new sump screen design requirements. See Section 3.p, Licensing Basis.

2. Material exclusion procedures exist to verify that no loose debris is left following any activity performed in containment once containment integrity has been established. STP M-45B, "Containment Inspection When Containment Integrity is Established," is implemented for at-power entries, requires that a visual inspection be performed, and any debris found during the inspection be removed from containment. This procedure also requires that all tools, equipment, and material used in a work activity be removed from containment (unless evaluated by engineering as acceptable).

3. An aggressive, ongoing containment cleaning program has been developed and implemented. This program has evolved over several years, and includes the following elements:

a. General Employee Training has been augmented to include a segment on the importance of maintaining the containments free of debris.
b. Routine work orders for cleaning containment prior to Mode 4 have been revised to include a detailed list of areas for cleaning and inspection.
c. Containment cleanup activities and inspections are now scheduled later in the outage. Containment inspections are performed by management personnel, radiation protection personnel, a senior licensed operator, and personnel knowledgeable of the containment environment. These improvements allow the efficient use of manpower, and assure that the containment is clean prior to entering Mode 4.
d. A containment cleanliness program has been established, and a program owner has been assigned. The program owner has the overall responsibility for containment cleanliness, and establishes procedures and necessary work orders to maintain clean containments.
e. Aggressive containment cleanup activities have been implemented to remove dirt and dust, including vacuuming of accessible cable trays and other accessible surfaces.

4. PG&E has inspection procedures to assure the containment sump screens are free of adverse gaps and breaches. STP M-45A, "Containment Inspection Prior to Establishing Containment Integrity," currently verifies by inspection that the screen surfaces are free of debris and that there are no gaps greater than the acceptable gap size. The acceptable gap size and screen hole size protect the minimum flow clearances in systems served by the pumps performing recirculation. This inspection is performed at the completion of each refueling outage.

5. Classroom and simulator training on indications of, and responses to, sump clogging have been included in operator initial and requalification training.

6. Training has been provided to engineering personnel to raise their awareness of the more aggressive containment cleanliness requirements, the potential for sump blockage, and actions being taken to address sump blockage concerns.

7. Training has been conducted for Emergency Response Organization decision makers and evaluators in the Technical Support Center on indications of sump blockage and compensatory actions.

8. To ensure that alternative water sources are available to refill the RWST, Emergency Operating Procedure (EOP) ECA-1.1, "Loss of Emergency Core Cooling," provides two methods to refill the RWST: (1) refill from the boric acid blender, and (2) refill from the spent fuel pool (SFP) via the SFP pumps. ECA-1.1 also provides guidance for injecting into the reactor coolant system (RCS) using the boric acid blender flow path, and into containment using either the boric acid blender, or the SFP flow path via the RWST to the CSS.

9. The following EOP changes have been implemented:

EOP E-1.3, "Transfer to Cold-leg Recirculation"

Three steps were added to this procedure to address the potential for sump blockage.

Step 11, "Reduce RHR [residual heat removal] flow as RCS [reactor coolant system] conditions permit: [followed by instructions for performing this action]," was added as a continuous action to reduce RHR flow and transport velocities to the containment sump after the recirculation alignment has been established. The step ensures that CS flow via RHR is secured if it is no longer needed. Then RHR flow control valves are throttled to approximately 400 gallons per minute (gpm) per train while maintaining core water level and thermocouple temperatures within satisfactory limits. The recirculation alignment is not changed (i.e., high head pumps receiving suction flow from the RHR pumps remain operating at full capacity).

Step 12, "Implement Appendix M, RWST Makeup," was added to begin refilling the RWST in accordance with the instructions of new Appendix M, "RWST Makeup."

Step 13, "Monitor for Containment Recirculation Sump Blockage: [followed by instructions for performing this action]," was added as a continuous action to monitor pump flows and motor amps for signs of loss of suction or cavitation. Action is directed to shut down pumps (high head pumps first) as necessary to prevent damage. Appropriate revised guidance has been included in the Unit 1 and Unit 2 procedures.

EOP E-1, "Loss of Reactor or Secondary Coolant"

EOP E-1 is re-entered after completion of the transfer to cold-leg recirculation. Actions pertinent to sump blockage must be continued. The following two steps were added:

Step 15, "Reduce RHR Flow as RCS Conditions Permit: [followed by instructions for performing this action]," was added to reduce RHR flow consistent with maintaining acceptable core level and temperature conditions. If RCS pressure is high enough to preclude significant RHR injection, then this step is bypassed.

Step 16, "Monitor for Containment Recirculation Sump Blockage: [followed by instructions for performing this action]," was added to continue monitoring for signs of sump blockage. Appropriate revised guidance has been included in the Unit 1 and Unit 2 procedures.

10. New EOP ECA-1.3, "Sump Blockage Guideline," was developed to provide specific guidance to operators when sump blockage has been diagnosed to have occurred. It is based on WCAP-16204, "Evaluation of Potential ERG [Emergency Response Guideline] and EPG [Emergency Procedure Guideline] Changes to Address NRC Bulletin 2003-01 Recommendations," which provides a generic evaluation of potential changes to the Westinghouse ERGs and Combustion Engineering EPGs to address NRC Bulletin 2003-01. Appropriate revised guidance has been included in the Unit 1 and Unit 2 procedures. Although testing and analysis demonstrate that the sump screen is capable of performing its required function for all accident conditions,

guidance for back-flushing the screen during recirculation has been included in Plant Engineering Procedure EN-1, "Post Accident Mitigation Diagnostic Aids and Guidelines," Attachment 8.9. The instructions for back-flushing are intended to be provided to an operator if required by EOP ECA-1.3.

The following physical changes have been or will be implemented for each unit:

Unit 1

During 1R14, PG&E installed a larger sump screen (with approximately five times the surface area of the sump screens upgraded in the tenth refueling outages, and 40 times the area of the original screens) that has passed plant-specific head loss testing for post-steam generator (SG) replacement debris loads.

PG&E either has implemented, or will implement, other physical improvements that include removal of selected debris sources, encapsulation of selected debris sources, and installation of debris interceptors. Specific improvements implemented during 1R14 include:

- Modification of the reactor cavity door (Door 278) to allow more debris to flow into the reactor cavity inactive sump;
- Addition of three approximately 18-inch high perforated plate debris interceptors on Doors 275, 276, and 277 in the crane wall (to capture RMI and unqualified coating chips);
- Removal of cable tray fire stops inside the crane wall (inside the pipe break ZOIs);
- Installation of multiple banding on cal-sil piping insulation inside the pipe break ZOIs;
- Installation of stainless steel jacketing on Temp-Mat piping insulation inside the pipe break ZOIs;
- Installation of tray covers to protect the pressurizer heater cable insulation in cable trays below the pressurizer; and
- Installation of stainless steel jacketed Temp-Mat insulation on the inlet to Pressurizer Safety Valves 8010B and 8010C.

The following actions will be completed during 1R15 in conjunction with SG replacement:

- Installation of RMI and stainless steel jacketed Temp-Mat on the replacement SGs; and
- Installation of stainless steel jacketed Temp-Mat insulation on Pressurizer Safety Valve 8010A (if required following replacement of valve internals).

Unit 2

During the Unit 2 Fourteenth Refueling Outage (2R14), PG&E installed a larger sump screen (with approximately 5 times the surface area of the sump screens upgraded in the tenth refueling outages, and 40 times the area of the original screens) that has passed plant-specific head loss testing for post-SG replacement debris loads.

PG&E also implemented other physical improvements that include removal of selected debris sources, encapsulation of selected debris sources, and installation of debris interceptors. Specific improvements implemented include:

- Modification of the reactor cavity door (Door 278-2) to allow more debris to flow into the reactor cavity inactive sump; and
- Addition of 3 approximately 18-inch high perforated plate debris interceptors on Doors 275-2, 276-2, and 277-2 in the crane wall (to capture RMI and unqualified coating chips).
- Installation of RMI and stainless steel jacketed Temp-Mat on the replacement SGs;
- Removal of cable tray fire stops inside the crane wall (inside the pipe break ZOIs);
- Installation of multiple banding on cal-sil piping insulation inside the pipe break ZOIs;
- Installation of stainless steel jacketing on Temp-Mat piping insulation inside the pipe break ZOIs;
- Installation of tray covers to protect the pressurizer heater cable insulation in cable trays below the pressurizer; and
- Installation of stainless steel jacketed Temp-Mat insulation on the inlet to Pressurizer Safety Valves 8010A, 8010B, and 8010C.

The upstream and downstream analyses in support of Generic Letter 2004-02 are complete.

Results of these analyses are discussed in Sections 3m, Downstream Effects – Components and Systems, and 3n, Downstream Effects – Fuel and Vessel.

3. Specific Information Regarding Methodology for Demonstrating Compliance

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.

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

PG&E Response:

- *State whether secondary line breaks were considered in the evaluation (e.g., main steam and feedwater lines) and briefly explain why or why not.*

Secondary system line breaks (e.g., feedwater or main steam line breaks) are not considered in this evaluation. The recirculation mode of emergency core cooling is only used for long term cooling following a LOCA. Secondary system line breaks (e.g., feedwater or main steam line breaks) are not considered in this evaluation since recirculation is not a concern for secondary line breaks because the RCS remains intact. With the RCS intact, RWST drain down is slower, and containment spray will be available as long as required to control containment pressure with water supplied from the RWST. Therefore, the recirculation mode of emergency core cooling is only used for long term cooling following a LOCA. See Section 1, Overall Compliance.

- *Describe and provide the basis for the break selection criteria used in the evaluation.*

Identification of possible break locations was accomplished through a review of the system flow diagrams, process and instrumentation diagrams, and piping isometric or other layout drawings. The piping systems inside containment were traced to the first isolation valve or to the containment boundary. This identified the possible locations within containment that needed to be considered for debris generation.

The following break locations from NEI 04-07, Volume 2, were considered:

- Break 1: Breaks in the RCS with the largest potential for debris generation.
- Break 2: Large breaks with two or more different types of debris.
- Break 3: Breaks in the most direct path to the sump.
- Break 4: Large breaks with the largest potential particulate debris to insulation ratio.
- Break 5: Breaks that generate a "thin bed" – high particulate with a thin fiber bed
- Break 6 Special case breaks.

For break selection, the only exception taken to NEI 04-07, Volumes 1 and 2, was the use of the criterion specifying "every five feet" as described in Section 3.3.5.2 of NEI 04-07, Volume 2. Due to the volume and configuration of DCPP's containment and the use of some conservative ZOIs, the overlapping ZOIs for everything except jacketed Temp-Mat and multi-banded cal-sil essentially covered the same locations. Additionally, all breaks generate similar quantities of debris from erosion of unjacketed fibrous materials, latent dirt/dust, miscellaneous debris, coatings in the ZOI (due to the use of a single limiting particulate quantity), and unqualified coating chips. Therefore, the approach used was to determine the potentially limiting debris generation locations to analyze based on proximity to potential fiber and cal-sil debris sources, and then determine the quantity and types of debris within the ZOI. This simplification of the process did not reduce the debris generation potential for the worst case conditions as described in Section 3.3 of NEI 04-07, Volumes 1 and 2.

Additionally, the "thin-bed" effect was given consideration during break selection. A "thin bed" can be created if a break generates a small amount of fibrous debris that can form a relatively uniform "thin bed" on the screen, and subsequently filter particulate and chemical precipitate to create significantly high head loss.

A review of the DCPP flow diagrams was performed to identify those lines connected to the RCS (up to the first isolation valve). The lines considered are:

- RCS loop piping (hot, cold, and crossover legs)
- Pressurizer surge line
- RHR hot-leg recirculation line
- Pressurizer relief valve inlet lines
- Pressurizer spray (normal and auxiliary)
- Safety injection (SI) lines
- Letdown and charging (normal and alternate)
- Reactor coolant pump (RCP) seal injection lines
- RCS sample and drain lines

The following is a list of the specific break locations which were analyzed in detail due to proximity of debris sources:

- Loop 1 crossover leg at SG nozzle (Unit 1 and Unit 2)
- Loop 1 crossover leg at RCP nozzle (Unit 1 and Unit 2)
- Loop 2 crossover leg at SG nozzle (Unit 1 and Unit 2)
- Loop 3 crossover leg at SG nozzle (Unit 1 and Unit 2)
- Loop 3 crossover leg at RCP nozzle (Unit 1 and Unit 2)
- Loop 4 crossover leg at SG nozzle (Unit 1 and Unit 2)
- Loop 4 crossover leg at RCP nozzle (Unit 1 and Unit 2)
- RHR hot-leg recirculation line near the crane wall at the junction with the Loop 4 hot-leg (Unit 1 and Unit 2)
- Pressurizer surge line near the crane wall, near the containment center line, and near the base of the pressurizer (Unit 1 and Unit 2)
- Line 727 loop seal line near the top of the pressurizer (Unit 1)
- Line 728 loop seal line near the top of the pressurizer (Unit 1 and Unit 2)
- Pressurizer spray line inside the pressurizer cubicle, near the top of the pressurizer (Unit 1 and Unit 2)

A summary of the six NEI 04-07, Volume 2, break scenarios follows.

Break No. 1 – Largest Potential for Debris

Cal-sil and fibrous insulation are known to present a challenge to sump operation when destroyed, and therefore, were important in determining break locations to analyze. DCPP's debris mitigation modifications were aimed at reducing both the cal-sil debris (by installing additional bands on cal-sil insulated piping) and the fibrous debris (by encapsulating fibrous insulation in stainless steel).

Even though the insulation is encapsulated, there remains significant fibrous insulation inside the pressurizer cubicle. The only significant source of fibrous debris remaining inside the crane wall after the debris reduction modifications at DCPP is the pressurizer heater cables. The Loop 2 crossover leg break at the SG nozzle and the pressurizer surge line near the base of the pressurizer are the only break locations which make the fiberglass on these cables a source of debris, and therefore, result in far more fibrous debris than any other break location inside the crane wall.

The three pressurizer safety valves in both units are each insulated with large quantities of fiberglass and are in close proximity to each other. The insulation on these valves was/will be replaced with encapsulated Temp-Mat insulation (two valves are complete in Unit 1, and the third will be completed in 1R15; Unit 2 was completed in 2R14). However, the installation of encapsulated Temp-Mat insulation only protects the insulation on one valve from breaks on the loop seals for the other two valves. The encapsulated insulation on the valve is destroyed if the break location is on the loop seal line for that valve. Two loop seal line breaks were analyzed for Unit 1. The Unit 1 Line 728 (the loop seal for the 8010B valve) break represented the limiting break location before installation of encapsulated Temp-Mat insulation, and the Line 727 (the loop seal for the 8010C valve) break represents the limiting break location after installation of encapsulated Temp-Mat insulation. In Unit 2, the break in Line 728 represents the limiting break location after installation of encapsulated Temp-Mat insulation. The limiting breaks for generation of fiberglass at DCPP are a break in Line 727 for Unit 1, and a break in Line 728 for Unit 2.

Break No. 2 – Large Breaks with Two or More Different Types of Debris

The aforementioned breaks on the Loop 2 crossover leg and the pressurizer loop seal lines generate the largest quantities of fiberglass insulation, but do not generate substantial cal-sil debris. Breaks on the Loop 4 crossover leg generate the largest quantity of cal-sil debris, with fibrous debris quantities similar to breaks on Loops 1 and 3.

Break No. 3 – Most Direct Path to the Sump

Breaks on Loops 3 and 4 will generate debris near the annulus door exiting near the sump. However, with the debris interceptors installed in each annulus door, there is little difference in the analyzed breaks as to the most direct path to the sump. In general, the transport fractions for the Loops 1 and 2 breaks are the same as for Loops 3 and 4, and in some cases, are greater than for Loops 3 and 4. See Section 3.e, Debris Transport.

Break No. 4 – Largest Potential Particulate Debris to Insulation Ratio

Breaks inside the crane wall (with the exception of the Loop 2 crossover leg break) generate similar quantities of fiberglass insulation. Latent fibrous debris, erosion of unjacketed fibrous materials, fibrous debris from mineral wool in elbows of cal-sil insulated piping (28.6D ZOI), and fibrous fire stop materials destroyed through open crane wall penetrations are very similar in quantity for all breaks inside the crane wall. Particulate coating debris is also similar in quantity for breaks inside the crane wall. Breaks on the Loop 2 crossover leg and pressurizer surge line generate mica particulate from the pressurizer heater cables, but also generate substantial quantities of fibrous insulation from the cables. Breaks on the Loop 4 crossover leg generate the largest quantity of cal-sil debris, with fiber similar to most other breaks inside the crane wall, and will therefore, be limiting with respect to the particulate to fiber insulation ratio. There are other breaks with a higher particulate to fiber ratio, but the overall debris quantities are insufficient to challenge post-accident sump operation. Breaks inside the pressurizer cubicle do not generate substantial cal-sil debris.

Break No. 5 – Breaks That Generate a "Thin Bed"

This break is one that could generate a relatively small amount of fibrous debris that, after its transport to the sump screen, could form a relatively uniform "thin bed" that could subsequently filter sufficient particulate and chemical precipitate debris to create a significantly high head loss, referred to as the "thin-bed" effect.

Through screen sizing, debris mitigation modifications, and installation of the debris interceptors, DCPP has ensured that there is some clean screen area for all breaks. This has subsequently been verified through testing.

Break No. 6 – Special Case Breaks

In order to bound all possible scenarios, additional breaks inside the pressurizer cubicle were examined (in addition to the loop seal line breaks). There are significant quantities of cal-sil and fibrous insulation inside the pressurizer cubicle, but the pressurizer surge line is below this and the concrete separating the upper and lower portions of the pressurizer protects the cubicle from breaks below the operating deck.

A break in the pressurizer spray line was also examined. The ZOI of a break in the spray line was determined to generate no cal-sil debris due to its proximity and geometry relative to cal-sil insulated piping. Although the debris target density at the top of the pressurizer is significant, the small ZOI (due to the 4-inch pipe diameter of the spray line) produces an amount of fibrous debris that is bounded by the loop seal line breaks.

- *Discuss the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance.*

Through screen sizing, debris mitigation modifications, and installation of debris interceptors, DCPP has ensured, and verified through testing, that there is some clean screen area for all breaks. All breaks generate similar quantities of debris from erosion of unjacketed fibrous materials, latent dirt/dust, miscellaneous debris (stickers, tags, labels, tape), coatings in the ZOI (particulate), and unqualified coating chips. Therefore, breaks that present the greatest challenge to post-accident sump performance are breaks that generate limiting amounts of cal-sil and fibrous debris. All areas with a significant potential to generate fibrous debris (Loop 2 crossover leg, pressurizer surge line, and pressurizer loop seal lines) have been analyzed. All areas with a significant potential to generate cal-sil debris (hot-leg, cold-leg, and crossover legs on all four loops) have been analyzed. Debris quantities have been calculated for any location which generates substantial quantities of fibrous insulation or cal-sil insulation.

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.

- *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.*
- *Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.*
- *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).*
- *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.*
- *Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.*

PG&E Response:

- *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.*

The debris generation calculation utilizes the ZOI refinement discussed in Section 4.2.2.1.1 of NEI 04-07, Volumes 1 and 2, which allows the use of debris-specific spherical ZOIs. Using this approach, the amount of debris generated within each ZOI is calculated and the individual contributions from each debris type are summed to arrive at a total debris source term. In certain cases, DCPP performed jet impingement testing to determine appropriate ZOIs as documented in WCAP-16720-P, "Jet Impingement Testing to Determine ZOIs for DCPP." In those cases where no information was available, the largest ZOI (28.6D) was conservatively used per NEI 04-07, Volume 2.

- *Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.*

Table 1 provides the destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.

- *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).*

DCPP has performed testing to determine the appropriate spherical-equivalent ZOIs for specified materials used inside containment. This testing was also used to demonstrate the performance of plant modifications designed to reduce or preclude damage to materials due to jet impingement during a LOCA. The testing was performed using a supply tank with subcooled fluid at 2000 pounds per square inch (psi) (+0/-50 psi) and 530°F (±25°F). The supply tank fluid volume was sufficiently large to allow for a 30-second blowdown with a nominal 3-inch nozzle. The initial fluid reservoir conditions were chosen so that test articles would be exposed to prototypical LOCA jet conditions in terms of pressure, temperature, time duration, and mass flux. To compensate for the fact that RCS conditions are 2250 psi, the test article was located such that the stagnation pressure at the point of jet impingement would be the same as using a supply tank at 2250 psi. The distance of the test article from the jet nozzle was calculated using the ANSI N58.2-1988 jet expansion model. This testing is documented in WCAP-16720-P and was performed under the direction of Westinghouse at Wyle Laboratories in Huntsville, Alabama. Table 2 summarizes the results of the testing.

- *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.*

The four most limiting break locations are shown in Figure 1. Tables 3 through 6 provide the debris quantities for these break locations.

- *Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.*

The total surface area of signs, placards, tags, tape, and similar miscellaneous material per unit are as follows:

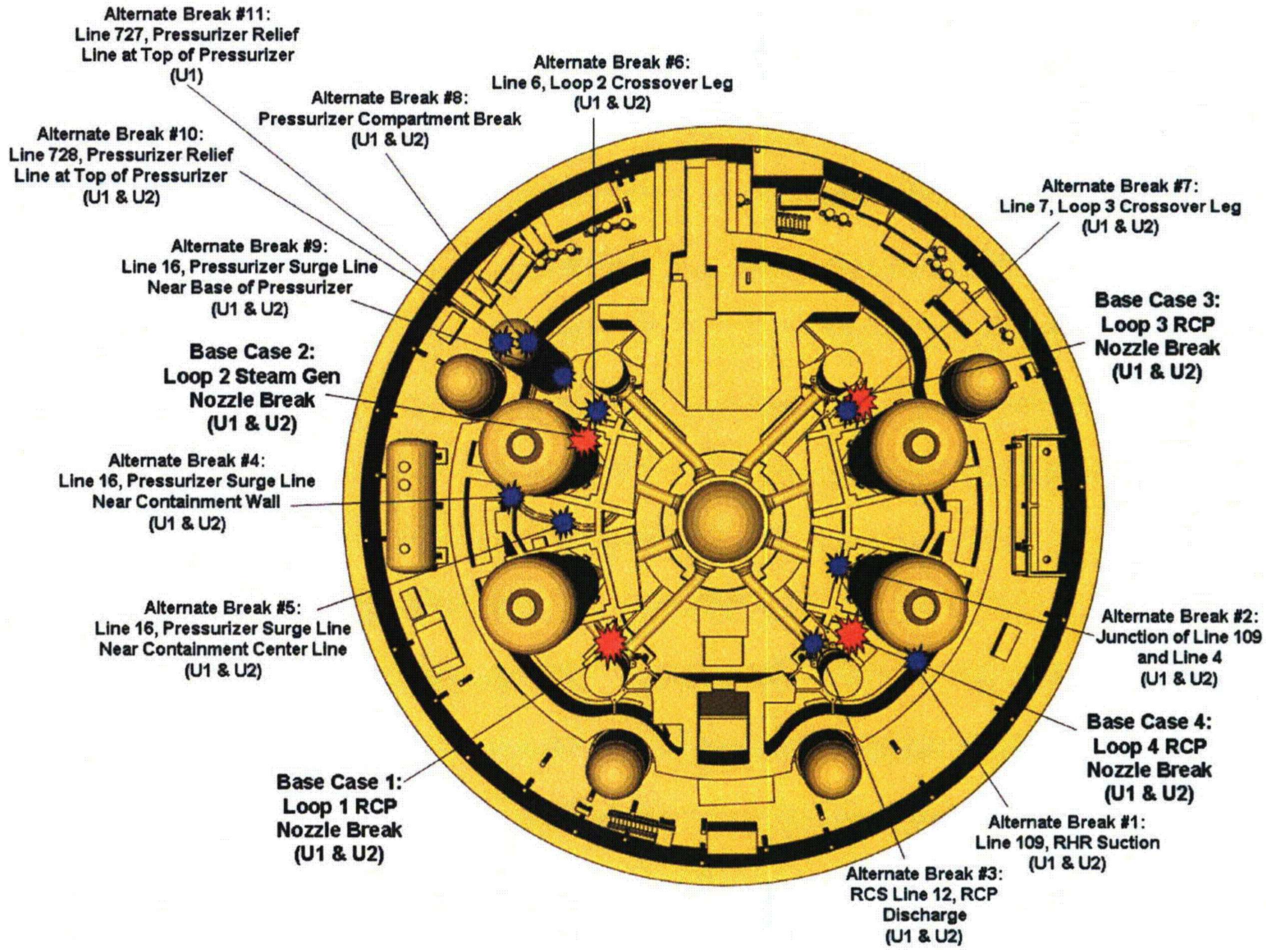
Miscellaneous Debris Materials Inside the Crane Wall:

Source Term	Characteristic Size	Area (ft^2)
Reflective Tape	1/8" to 1/2" pieces	116.1
Black Lettering Tape	1/8" to 1/2" pieces	19.8
Conduit Tape	1/8" to 1/2" pieces	21.3
Lamicoids	1/8" to 1/2" pieces	7.2
Electric Tape	1/8" to 1/2" pieces	10.7
Stickers/Labels	1/8" to 1/2" pieces	20.3
Cable Ties	1/8" to 1/2" pieces	4.8
RP Survey Tags	1/8" to 1/2" pieces	5.5
		Total – 205.7

Miscellaneous Debris Materials Outside the Crane Wall:

Source Term	Characteristic Size	Area (ft^2)
Stickers/Labels	1/8" to 1/2" pieces	15.1
		Total – 15.1

Figure 1 – Break Locations



Note: Breaks at the S/G nozzle side of the crossover legs were analyzed in detail in prior revisions of the analysis.

Table 1 – Destruction ZOIs and Debris Sources

Debris Source	NRC ZOI (ZOI Radius/ Break Diameter)	ZOI Used (ZOI Radius/ Break Diameter)	Comment
Temp-Mat (with Stainless Steel Wire Retainer)	11.7	11.7	
Temp-Mat with Stainless Steel Wire Mesh, encapsulated in 0.003" Thick Stainless Steel Cladding	-	3.7	See Note 1
Mineral Wool	-	28.6	See Note 2
RMI (Mirror with Standard Bands)	28.6	28.6	See Note 3
Transco RMI on Replacement SGs	2.0	2.0	See Note 3
Cal-Sil (Stainless Steel Cladding with Stainless Steel Banding on 3" Centers)	-	3.0	See Note 1
Cal-Sil (Stainless Steel Cladding with Stainless Steel Banding on 12" Centers)	5.45	5.5	
Vapor Barrier Material	-	3.0	See Note 4
Aluminum Tape	-	28.6	See Note 2
Cable Tray Fire Stop Materials (Kaowool, Marinite, RTV Foam)	-	28.6	See Note 2
Cable Insulation/Jackets (XLPE, SR, EPR, Hypalon)	-	5.0	See Note 1
Pressurizer Heater Cables (Fiberglass Overbraid, Mica Tape, Flexicone 200 Sleeving, 3M Arc Prevention Tape)	-	5.0	See Note 1
Light Bulbs	-	28.6	See Note 2
Qualified Coatings		5.0	See Note 5
Miscellaneous Debris (Tags, Tape, Stickers, Cable Ties)	-	28.6	See Note 2

Note 1 ZOI is based on the jet impingement testing documented in WCAP-16720-P.

Note 2 Where there is no data available in NEI 04-07, Volumes 1 and 2, the largest ZOI provided is conservatively used.

Note 3 The NRC ZOI for Mirror RMI with standard bands is 28.6, the ZOI for Mirror with Sure-Hold bands is 2.4, and the ZOI for Transco and Darchem RMI is 2.0; without any specific destruction pressure data for the Johns-Manville RMI used on piping and the pressurizer at DCPP, a conservative ZOI of 28.6 is used. For the Transco RMI used on the replacement SGs, a ZOI of 2.0 is used.

Note 4 The surface area of the vapor barrier destroyed is equal to the surface area of the destroyed cal-sil; therefore, vapor barrier debris quantity is derived using the cal-sil ZOI and debris calculations.

Note 5 ZOI is based on the jet impingement testing documented in WCAP-16568-P.

Table 2 – Results of Destruction Testing

Test Article(s)	Tested ZOI	Observations
Electrical Cables (Continental Wire, Raychem, Pressurizer Heater Cables)	5D	Specimens in good shape with some fraying and discoloration. Abrasion of Raychem cable.
Covered (stainless steel) pressurizer heater cable tray	2D	Holding straps remained in place with stainless steel cover crushed. The cable in the footprint of the cable tray opening was missing insulation.
Covered (stainless steel) pressurizer heater cable tray mounted 45° to jet	2D	Cable tray cover bent inward, but without completely collapsing. The cables outside the tray were completely stripped of insulation, along with cables inside the footprint of the cable tray opening. The 3M tape around the cables outside of the tray was destroyed.
Cal-Sil insulation mounted on a 2" schedule 160 pipe with one layer of stainless steel jacketing with banding installed at 3" intervals	3D	Banding clamps were displaced, but did not unlatch. The stainless steel jacketing was bent and torn between clamps. Minor moisture intrusion occurred, but cal-sil was intact. A minor loss of material at the ends of the specimen was noted.
4" round by 18" long Temp-Mat with stainless steel jacketing and seams tied with hog rings	3D	There was a V-shaped tear on the specimen with a tear on the opposite end. There was a 1" round tear in one specimen with no apparent extrusion of Temp-Mat.
6" by 24" by 2" rectangular Temp-Mat with stainless steel jacketing and seams tied with hog rings	3.7D	The specimen was compressed with a minor indentation on the front. The jacketing had minor tears at the corners, but none of the hog rings were torn through the jacketing.
Temp-Mat (wrapped in SS mesh) rolled onto a 2" schedule 160 pipe, secured with wire ties spaced 3" apart; covered with a single layer of stainless steel jacketing banded on 4" centers	3.7D	Four bands were removed from the jacketing. There was no damage to the Temp-Mat or the stainless steel mesh

Table 3 - Debris for Crossover Leg Break at Reactor Coolant Pump 4 Nozzle

Inside ZOI		Crossover Leg Break at RCP 4 Nozzle							
Debris Type	**Debris Size**	**Unit 1 Debris Quantity**				**Unit 2 Debris Quantity**			
Stainless Steel RMI	Small Pieces (<4")	21,700	ft^2	-		21,700	ft^2	-	
	Large Pieces (>4")	7,240	ft^2	-		7,240	ft^2	-	
3M Foil Tape	Small Pieces (<4")	370	ft^2	-		370	ft^2	-	
Temp-Mat	Fines	0.00	ft^3	0.00	lb.	0.12	ft^3	1.37	lb.
Cal-Sil	Fines	4.16	ft^3	60.32	lb.	4.16	ft^3	60.32	lb.
Kaowool Blanket	Fines	0.10	ft^3	0.60	lb.	0.10	ft^3	0.60	lb.
Kaowool M Board	Fines	0.64	ft^3	10.88	lb.	0.64	ft^3	10.88	lb.
Marinite M Board	Fines	0.74	ft^3	34.04	lb.	0.74	ft^3	34.04	lb.
Mineral Wool in Pipe Fittings	Fines	1.93	ft^3	15.44	lb.	1.93	ft^3	15.44	lb.
Vapor Barrier Material	1/8" to 1/2" pieces	19.50	ft^2	-		19.50	ft^2	-	
RTV Foam	1/8" to 1/2" pieces	3.60	ft^3	67.32	lb.	3.60	ft^3	67.32	lb.
Light Bulbs	1/8" to 1/2" pieces	133.00	ft^2	-		133.00	ft^2	-	
Reflective Tape (Outside Crane Wall)	1/8" to 1/2" pieces	4.50	ft^2	-		4.50	ft^2	-	
Conduit Tape (Outside Crane Wall)	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Fiberglass (PZR Heater Cables)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Fiberglass (Flexicone Sleeving)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Silicone Rubber (Flexicone Sleeving)	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Mica Tape (PZR Heater Cables)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
3M Arc Prevention Tape	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Cable Ties	Fines	0.00	ft^2	-		0.00	ft^2	-	
Qualified Ameron 66	Fines	0.18	ft^3	17.80	lb.	0.18	ft^3	17.80	lb.
Qualified CZ-11	Fines	0.24	ft^3	53.70	lb.	0.24	ft^3	53.70	lb.
Qualified Phenoline 305	Fines	0.48	ft^3	50.60	lb.	0.48	ft^3	50.60	lb.
Outside ZOI									
Unjacketed Temp-Mat	Fines	0.11	ft^3	1.33	lb.	0.38	ft^3	4.43	lb.
Unjacketed Cerablanket	Fines	0.00	ft^3	0.00	lb.	0.07	ft^3	0.55	lb.
Uncovered Fire Stop Kaowool	Fines	0.38	ft^3	2.28	lb.	0.38	ft^3	2.28	lb.
Unqualified IOZ	Fines	2.00	ft^3	446.00	lb.	2.00	ft^3	446.00	lb.
Unqualified Alkyd	9-mil chips	38.85	ft^3	4079.25	lb.	38.85	ft^3	4079.25	lb.
Unqualified High Heat Aluminum	2-mil chips	0.08	ft^3	8.00	lb.	0.08	ft^3	8.00	lb.

Table 4 - Debris for Crossover Leg Break at Steam Generator 2 Nozzle

Inside ZOI		Crossover Leg Break at SG 2 Nozzle							
Debris Type	**Debris Size**	**Unit 1 Debris Quantity**				**Unit 2 Debris Quantity**			
Stainless Steel RMI	Small Pieces (<4")	20,800	ft^2	-		20,800	ft^2	-	
	Large Pieces (>4")	6,950	ft^2	-		6,950	ft^2	-	
3M Foil Tape	Small Pieces (<4")	370	ft^2	-		370	ft^2	-	
Temp-Mat	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Cal-Sil	Fines	0.94	ft^3	13.64	lb.	0.98	ft^3	14.27	lb.
Kaowool Blanket	Fines	0.02	ft^3	0.12	lb.	0.02	ft^3	0.12	lb.
Kaowool M Board	Fines	0.46	ft^3	7.82	lb.	0.46	ft^3	7.82	lb.
Marinite M Board	Fines	0.74	ft^3	34.04	lb.	0.74	ft^3	34.04	lb.
Mineral Wool in Pipe Fittings	Fines	1.91	ft^3	15.28	lb.	1.91	ft^3	15.28	lb.
Vapor Barrier Material	1/8" to 1/2" pieces	4.80	ft^2	-		4.48	ft^2	-	
RTV Foam	1/8" to 1/2" pieces	2.36	ft^3	44.13	lb.	2.36	ft^3	44.13	lb.
Light Bulbs	1/8" to 1/2" pieces	133.00	ft^2	-		133.00	ft^2	-	
Reflective Tape (Outside Crane Wall)	1/8" to 1/2" pieces	7.29	ft^2	-		7.29	ft^2	-	
Conduit Tape (Outside Crane Wall)	1/8" to 1/2" pieces	2.27	ft^2	-		2.27	ft^2	-	
Fiberglass (PZR Heater Cables)	Fines	0.18	ft^3	23.20	lb.	0.22	ft^3	28.64	lb.
Fiberglass (Flexicone Sleeving)	Fines	0.06	ft^3	7.58	lb.	0.07	ft^3	9.00	lb.
Silicone Rubber (Flexicone Sleeving)	1/8" to 1/2" pieces	33.05	ft^2	-		39.27	ft^2	-	
Mica Tape (PZR Heater Cables)	Fines	0.29	ft^3	21.75	lb.	0.36	ft^3	26.85	lb.
3M Arc Prevention Tape	1/8" to 1/2" pieces	5.60	ft^2	-		5.60	ft^2	-	
Cable Ties	1/8" to 1/2" pieces	0.19	ft^2	-		0.19	ft^2	-	
Qualified Ameron 66	Fines	0.18	ft^3	17.80	lb.	0.18	ft^3	17.80	lb.
Qualified CZ-11	Fines	0.24	ft^3	53.70	lb.	0.24	ft^3	53.70	lb.
Qualified Phenoline 305	Fines	0.48	ft^3	50.60	lb.	0.48	ft^3	50.60	lb.
Outside ZOI									
Unjacketed Temp-Mat	Fines	0.11	ft^3	1.33	lb.	0.38	ft^3	4.43	lb.
Unjacketed Cerablanket	Fines	0.00	ft^3	0.00	lb.	0.07	ft^3	0.55	lb.
Uncovered Fire Stop Kaowool	Fines	0.38	ft^3	2.28	lb.	0.38	ft^3	2.28	lb.
Unqualified IOZ	Fines	2.00	ft^3	446.00	lb.	2.00	ft^3	446.00	lb.
Unqualified Alkyd	9-mil chips	38.85	ft^3	4079.25	lb.	38.85	ft^3	4079.25	lb.
Unqualified High Heat Aluminum	2-mil chips	0.08	ft^3	8.00	lb.	0.08	ft^3	8.00	lb.

Table 5 - Debris for Pressurizer Relief Valve Inlet Breaks (Unit 1 Line 727; Unit 2 Line 728)

Inside ZOI		PZR RV Inlet Breaks (U1-Line 727;U2-Line 728)							
Debris Type	**Debris Size**	**Unit 1 Debris Quantity**				**Unit 2 Debris Quantity**			
Stainless Steel RMI	Small Pieces (<4")	6,710	ft^2	-		6,710	ft^2	-	
	Large Pieces (>4")	2,240	ft^2	-		2,240	ft^2	-	
3M Foil Tape	Small Pieces (<4")	370	ft^2	-		370	ft^2	-	
Temp-Mat	Fines	5.65	ft^3	66.67	lb.	1.58	ft^3	18.64	lb.
Cal-Sil	Fines	1.05	ft^3	15.23	lb.	1.05	ft^3	15.23	lb.
Kaowool Blanket	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Kaowool M Board	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Marinite M Board	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Mineral Wool in Pipe Fittings	Fines	0.61	ft^3	4.91	lb.	0.61	ft^3	4.91	lb.
Vapor Barrier Material	1/8" to 1/2" pieces	7.15	ft^2	-		7.15	ft^2	-	
RTV Foam	1/8" to 1/2" pieces	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Light Bulbs	1/8" to 1/2" pieces	133.00	ft^2	-		133.00	ft^2	-	
Reflective Tape (Outside Crane Wall)	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Conduit Tape (Outside Crane Wall)	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Fiberglass (PZR Heater Cables)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Fiberglass (Flexicone Sleeving)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Silicone Rubber (Flexicone Sleeving)	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Mica Tape (PZR Heater Cables)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
3M Arc Prevention Tape	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Cable Ties	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Qualified Ameron 66	Fines	0.04	ft^3	3.90	lb.	0.04	ft^3	3.90	lb.
Qualified CZ-11	Fines	0.03	ft^3	7.40	lb.	0.03	ft^3	7.40	lb.
Qualified Phenoline 305	Fines	0.07	ft^3	7.00	lb.	0.07	ft^3	7.00	lb.
Outside ZOI									
Unjacketed Temp-Mat	Fines	0.11	ft^3	1.33	lb.	0.38	ft^3	4.43	lb.
Unjacketed Cerablanket	Fines	0.00	ft^3	0.00	lb.	0.07	ft^3	0.55	lb.
Uncovered Fire Stop Kaowool	Fines	0.38	ft^3	2.28	lb.	0.38	ft^3	2.28	lb.
Unqualified IOZ	Fines	2.00	ft^3	446.00	lb.	2.00	ft^3	446.00	lb.
Unqualified Alkyd	9-mil chips	38.85	ft^3	4079.25	lb.	38.85	ft^3	4079.25	lb.
Unqualified High Heat Aluminum	2-mil chips	0.12	ft^3	12.23	lb.	0.12	ft^3	12.23	lb.

Table 6 - Debris for Pressurizer Surge Line Break Near Base of Pressurizer

Inside ZOI		PZR Surge Line Break near PZR Base							
Debris Type	**Debris Size**	**Unit 1 Debris Quantity**				**Unit 2 Debris Quantity**			
Stainless Steel RMI	Small Pieces (<4")	15,300	ft^2	-		15,300	ft^2	-	
	Large Pieces (>4")	5,100	ft^2	-		5,100	ft^2	-	
3M Foil Tape	Small Pieces (<4")	370	ft^2	-		370	ft^2	-	
Temp-Mat	Fines	1.32	ft^3	15.58	lb.	1.32	ft^3	15.58	lb.
Cal-Sil	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Kaowool Blanket	Fines	0.02	ft^3	0.12	lb.	0.02	ft^3	0.12	lb.
Kaowool M Board	Fines	0.19	ft^3	3.23	lb.	0.19	ft^3	3.23	lb.
Marinite M Board	Fines	0.74	ft^3	34.04	lb.	0.74	ft^3	34.04	lb.
Mineral Wool in Pipe Fittings	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.
Vapor Barrier Material	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
RTV Foam	1/8" to 1/2" pieces	1.01	ft^3	18.89	lb.	1.01	ft^3	18.89	lb.
Light Bulbs	1/8" to 1/2" pieces	133.00	ft^2	-		133.00	ft^2	-	
Reflective Tape (Outside Crane Wall)	1/8" to 1/2" pieces	3.50	ft^2	-		3.50	ft^2	-	
Conduit Tape (Outside Crane Wall)	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-	
Fiberglass (PZR Heater Cables)	Fines	0.12	ft^3	16.38	lb.	0.12	ft^3	16.38	lb.
Fiberglass (Flexicone Sleeving)	Fines	0.12	ft^3	15.15	lb.	0.14	ft^3	18.00	lb.
Silicone Rubber (Flexicone Sleeving)	1/8" to 1/2" pieces	66.10	ft^2	-		78.50	ft^2	-	
Mica Tape (PZR Heater Cables)	Fines	0.20	ft^3	15.34	lb.	0.20	ft^3	15.34	lb.
3M Arc Prevention Tape	1/8" to 1/2" pieces	5.60	ft^2	-		5.60	ft^2	-	
Cable Ties	1/8" to 1/2" pieces	0.19	ft^2	-		0.19	ft^2	-	
Qualified Ameron 66	Fines	0.04	ft^3	3.90	lb.	0.04	ft^3	3.90	lb.
Qualified CZ-11	Fines	0.03	ft^3	7.40	lb.	0.03	ft^3	7.40	lb.
Qualified Phenoline 305	Fines	0.07	ft^3	7.00	lb.	0.07	ft^3	7.00	lb.
Outside ZOI									
Unjacketed Temp-Mat	Fines	0.11	ft^3	1.33	lb.	0.38	ft^3	4.43	lb.
Unjacketed Cerablanket	Fines	0.00	ft^3	0.00	lb.	0.07	ft^3	0.55	lb.
Uncovered Fire Stop Kaowool	Fines	0.38	ft^3	2.28	lb.	0.38	ft^3	2.28	lb.
Unqualified IOZ	Fines	2.00	ft^3	446.00	lb.	2.00	ft^3	446.00	lb.
Unqualified Alkyd	9-mil chips	38.85	ft^3	4079.25	lb.	38.85	ft^3	4079.25	lb.
Unqualified High Heat Aluminum	2-mil chips	0.08	ft^3	8.00	lb.	0.08	ft^3	8.00	lb.

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.

Provide the assumed size distribution for each type of debris.

- *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.*
- *Provide assumed specific surface areas for fibrous and particulate debris.*
- *Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.*

PG&E Response:

- *Provide bulk densities (i.e., including voids between fibers/particles) and material densities (i.e., the density of the microscopic fibers/particles themselves) for fibrous and particulate debris.*

- *Provide the assumed size distribution for each type of debris.*

Table 1 summarizes the debris characteristics.

RMI

It is assumed that 75 percent of the RMI stainless steel inner foils generate debris 4 inches and smaller, and 25 percent of the foils generate debris between 4 inches and 6 inches (reference NUREG/CR-6808). These are defined as small pieces and large pieces, respectively. NEI 04-07, Volume 1, follows this assumption (reference Section 3.4.3.3.2), with the assumption that 4 inches is bounding as the largest size that can transport. It specifies a 75 percent/25 percent split between small pieces and large pieces, using the same figure in NUREG/CR-6808.

Temp-Mat

Temp-Mat is a high-density fiberglass product manufactured by JPS Corporation and consists of glass fibers needled into a felt mat. Per NEI 04-07, Volume 1, Table 3-2, Temp-Mat has a macroscopic (as fabricated) density of 11.8 lbm/ft^3, a microscopic density of 162 lbm/ft^3 and an individual fiber diameter of 9 microns.

As part of PG&E's fibrous debris mitigation efforts, many of the Temp-Mat insulation targets inside the crane wall and inside the pressurizer cubicle have been replaced with a jet tested insulation configuration, which is constructed using Temp-Mat pads with stainless steel mesh that are encapsulated in 0.003-inch thick stainless steel cladding. Jet testing of this configuration has shown that it protects the contained fibrous insulation at a ZOI of 3.7D. If this insulation is closer than 3.7D to a particular break, it is assumed to be destroyed as 100 percent fines. For unjacketed Temp-Mat outside a ZOI, 0.625 percent of the total volume is assumed to erode as fines. See Section 3.i, Debris Source Term, for details of erosion testing.

Cerablanket

Cerablanket is a ceramic fiber blanket produced by Thermal Ceramics. It is similar to Kaowool. The macroscopic density of Cerablanket was taken as 8 lbm/ft^3 (this being the maximum as-manufactured density for 1-inch thick Cerablanket). Using the argument that it is similar in construction to Kaowool, the values of material density and characteristic size for Kaowool were taken from Table 3-2 of NEI 04-07, Volume 1. These values are 161 lbm/ft^3 and 2.7 to 3.0 micron, respectively. Through the debris reduction modifications at DCPP, there are no Cerablanket targets inside any ZOI. The only source of Cerablanket debris is erosion of unjacketed Cerablanket targets which are outside any ZOI, for which 3 percent of the total volume is assumed to erode as fines. See Section 3.i, Debris Source Term, for details of erosion testing.

Mineral Wool

Mineral wool is a generic name for families of products made by Rock Wool, Roxul, Fibrex, IIG, and others. The term, mineral wool, typically refers to two types of insulation: (1) rock wool, a manmade material consisting of natural minerals like basalt or diabase; or (2) slag wool, a manmade material from blast furnace slag. Per Table 3-2 of NEI 04-07, Volume 1, mineral wool has a macroscopic density ranging from 4 to 10 lbm/ft^3, a microscopic density of 90 lbm/ft^3, and an individual fiber diameter of 5 to 7 microns. Based on Section 4.141 of DCPP Specification 8737, a macroscopic (as fabricated) density of 8 lbm/ft^3 was used for the mineral wool in the elbows of cal-sil insulated piping (this is the only mineral wool inside a ZOI). A ZOI of 28.6D is used, along with a debris size distribution of 100 percent fines.

Min-K

NEI 04-07, Volume 1, Table 3-2, gives a range of bulk density for Min-K from 8-16 lbm/ft^3, with a characteristic size defined as, less than 0.1 micron. Through the debris reduction modifications performed at DCPP, there are no Min-K targets inside any ZOI. There are Min-K targets remaining in containment, but they are of negligible quantity and are in the containment annulus. These Min-K targets are covered to preclude erosion from CS.

Cal-Sil

Table 3-2 of NEI 04-07, Volume 1, states that the as-fabricated density of cal-sil is 14.5 lbm/ft^3, and the material density is 144 lbm/ft^3. The characteristic size of cal-sil is a 5 micron mean particle per Table 3-2 of NEI 04-07, Volume 1.

Jet impact testing performed by DCPP (for details see Section 3.b, Debris Generation/Zone of Influence [ZOI] excluding coatings) has shown that installation of additional stainless steel banding (with maximum center to center spacing of 3 inches) prevents destruction of cal-sil insulation at a distance of 3D. Therefore, DCPP uses a 3D spherical ZOI for cal-sil insulated piping inside the crane wall. If cal-sil insulation inside the crane wall is closer than 3D to a particular break, it is assumed to be destroyed as 100 percent fines. A ZOI of 5.5D and a debris size distribution of 100 percent fines is used for cal-sil insulation inside the pressurizer cubicle, which does not have additional banding installed.

PG&E installed multiple banding on cal-sil piping insulation inside the pipe break ZOIs for Unit 1 during 1R14; and will install it on Unit 2 during 2R14. See Section 2, General Description of and Schedule for Corrective Actions.

Vapor Barrier Material

Vapor barrier material is bonded to the underside of stainless steel jacketing for cal-sil insulated piping and equipment.

The vapor barrier material consists of a 1-mil thick polyethylene sheet with a 3-mil thick Kraft paper. The macroscopic (as fabricated) density of the vapor barrier material is conservatively based on the density of the polyethylene sheet. High density polyethylene has a macroscopic density of 57.4 lbm/ft^3. It is assumed to be destroyed as small pieces in the range of 1/8 inch x 1/8 inch to 1/2 inch x 1/2 inch, large enough to block holes on the sump screen, but small enough to be readily transportable. The surface area of the vapor barrier destroyed is equal to the surface area of the destroyed cal-sil, therefore, the vapor barrier debris quantity is derived using the cal-sil ZOI and debris calculations.

Aluminum Tape

The aluminum tape used is 3M product #425, and it has a macroscopic (as fabricated) density of 124.8 lbm/ft^3. A ZOI of 28.6D is used for aluminum tape, and it is assumed to fail as the smallest RMI foil debris size (between 1/4 inch and 4 inches). Aluminum tape is conservatively assumed to both block holes in the sump screen and completely dissolve in the post-LOCA recirculation pool (to form chemical precipitates).

Kaowool (Blanket and Board)

Kaowool is produced from kaolin, a naturally occurring alumina-silica fire clay. The Kaowool blankets used in fire stops are manufactured by Thermal Ceramics and have been procured in both 4 lbm/ft^3 and 6 lbm/ft^3 blankets. Conservatively, a value of 6 lbm/ft^3 was used. The Kaowool M board used in fire stops has a macroscopic (as fabricated) density of 17 lbm/ft^3. Per NEI 04-07, Volume 1 (Table 3-2), Kaowool has a microscopic density of 161 lbm/ft^3 and an individual fiber diameter of 2.7 to 3.0 microns. As part of DCPP's debris reduction modifications, all fire stops inside the Unit 1 crane wall have been removed, and the few remaining fire stops inside the Unit 2 crane wall will be removed during 2R14. The only remaining destruction of fire stops in a ZOI is through open penetrations in the crane wall. The Kaowool in these fire stops (both board and blanket) is taken to fail as 100 percent fines. Uncovered fire stops in the annulus are also subjected to CS and depending on the orientation of the fire stop, some volume (ranging between 5 percent and 37 percent) of the uncovered Kaowool is assumed to erode as fines. See Section 3.i, Debris Source Term, for details of erosion testing.

RTV Foam

The Silicone RTV Foam used in the fire stops (Dow Corning) has a macroscopic (as fabricated) density of 18.7 lbm/ft^3. RTV foam in fire stops that are destroyed through open penetrations in the crane wall is assumed to fail as small pieces in the range of 1/8 inch x 1/8 inch to 1/2 inch x 1/2 inch, large enough to block holes on the sump screen, but small enough to be readily transportable.

Marinite M Panel

The Marinite M Fireproof Marine Joiner Panel and the Marinite XL Panel it replaced are very similar in composition and have the same density. The Marinite M and XL panels are formed from cal-sil, and have a macroscopic (as-fabricated) density of 46 lbm/ft^3. A microscopic density of 144 lbm/ft^3 and a characteristic size of 5 microns is used based on the cal-sil data in Table 3-2 of NEI 04-07, Volume 1, and Scanning Electron Microscope material evaluations. The Marinite panels used in fire stops which are destroyed through open crane wall penetrations is taken to fail as 100 percent fines.

Cable Insulation/Cable Jackets

Cable insulation and cable jacket materials include XLPE, EPR, SR, and Hypalon. The Continental cables (with SR jackets) also contain core rope, wrapping strands, woven fiberglass sheathing, aluminum foil, and cellophane. Using the ZOI for these cables which was found during DCPP jet impingement testing (5D), DCPP has determined that none of these cable materials are in any ZOI.

Pressurizer Heater Cable Insulation/Jackets and Flexicone 200 Sleeving

The pressurizer heater cables are insulated with both mica tape and a fiberglass overbraid.. Mica tape contains both mica and fiberglass tape. Per vendor information, it was determined that 82.4 percent of the mica tape is mica and the remaining 17.6 percent is fiberglass tape. Material data sheets for mica indicate a characteristic particle size for mica ranging between 1 and 55 microns. It is assumed that mica is destroyed as fines with a particle size of 17.3 microns (same as latent dirt/dust), and the surrogate material for latent dirt/dust (PWR dirt mix) was used during head loss tests to represent the mica. The fiberglass tape is assumed to be destroyed as fines, and shredded fiberglass tape was used during head loss tests to represent the fiberglass tape constituent of mica tape. The macroscopic density of the mica tape is derived from vendor input as 74.88 lbm/ft^3. The macroscopic density of the fiberglass overbraid on the pressurizer heater cables was experimentally determined to be 132.57 lbm/ft^3. The fiberglass overbraid is conservatively assumed to be destroyed as fines which are assumed to be equivalent to Nukon fines.

Flexicone 200 sleeving is a high temperature silicone rubber elastomer pressure bonded to a fiberglass braid. The silicone rubber constituent of this sleeving is assumed to be destroyed as small pieces in the range of 1/8-inch x 1/8-inch to 1/2-inch x 1/2-inch pieces, large enough to block holes on the sump screen, but small enough to be readily transportable. The macroscopic density of the silicone rubber in the Flexicone 200 sleeving was derived from vendor input as 58 lbm/ft^3. The macroscopic density of the fiberglass braid constituent of the Flexicone 200 sleeving was derived from vendor input as 127.3 lbm/ft^3. The fiberglass braid constituent of this sleeving is conservatively assumed to be destroyed as fines which are assumed to be equivalent to Nukon fines.

In certain areas, the pressurizer heater cables are wrapped with 3M Arc Prevention Tape. 3M Arc Prevention Tape is assumed to fail as 1/8-inch x 1/8-inch to 1/2-inch x 1/2-inch pieces, large enough to block holes on the sump screen, but small enough to be readily transportable.

Light Bulbs

The light bulb glass has a macroscopic density of 136.2 lbm/ft^3. The light bulbs are assumed to be destroyed as small pieces in the range of 1/8 inch x 1/8 inch to 1/2 inch x 1/2 inch, large enough to block holes on the sump screen, but small enough to be readily transportable.

Latent Debris and Miscellaneous Debris

The values presented in NEI 04-07, Volume 2, are used for the density and characteristic size of the dust/dirt (169 lbm/ft^3, 17.3 micron spherical particle), and latent fiber (94 lbm/ft^3 material density, 2.4 lbm/ft^3 dry bed density, 7 micron fiber diameter). In accordance with NEI 04-07, Volume 2 (Section 3.5.2), 15 percent of latent debris is categorized as latent fiber.

The miscellaneous debris (i.e. equipment tags, tape, and stickers) outside the crane wall is conservatively assumed to fail as intact items. The miscellaneous debris inside the crane wall is assumed to be destroyed as small pieces in the range of 1/8 inch x 1/8 inch to 1/2 inch x 1/2 inch, large enough to block holes on the sump screen, but small enough to be readily transportable.

- *Provide assumed specific surface areas for fibrous and particulate debris.*

Since the head loss across the installed sump screen was determined via testing, specific surface areas are not used in the design basis for DCPP.

- *Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.*

DCPP has not used any debris characterization assumptions that deviate from NRC-approved guidance.

Table 1 – Debris Characteristics

Debris Source	Macroscopic Density (lbs/ft^3)	Microscopic Density (lbs/ft^3)	Characteristic Size
RMI	-	-	Small pieces (≤ 4") Large pieces (> 4")
Temp-Mat	11.8	162	9 µm [(1)]
Cerablanket	8	161	2.7 to 3.0 µm [(1)]
Mineral Wool	8	90	5 to 7 µm [(1)]
Min-K	16	-	<0.1 µm [(2)]
Cal-Sil	14.5	144	5 µm [(2)]
Vapor Barrier Material	57.4	-	1/8" to 1/2" pieces
Aluminum Tape	124.8	-	1/4" to 4" pieces
Cable Tray Fire Stops: - Kaowool Blanket - Kaowool M Board - RTV Foam - Marinite	 6 17 18.7 46	 161 161 - 144	 2.7 to 3.0 µm [(1)] 2.7 to 3.0 µm [(1)] 1/8" to 1/2" pieces 5 µm [(2)]
Pressurizer Heater Cables: - Fiberglass Overbraid - Mica Tape - Flexicone Sleeving (Fiberglass) - Flexicone Sleeving (Silicone Rubber) - 3M Arc Prevention Tape	 132.6 74.9 127.3 58.0 -	 - - - - -	 7 µm 17.3 µm 7 µm 1/8" to 1/2" pieces 1/8" to 1/2" pieces
Glass - Light Bulbs	136.2	-	1/8" to 1/2" pieces
Latent Debris: - Dirt/Dust - Fiber	 - -	 169 94	 17.3 µm [(2)] 7 µm [(1)]
Miscellaneous Latent Debris: - Tags, Tape, Stickers - Cable Ties	 - -	 - -	 1/8" to 1/2" pieces intact cable ties

(1) Fiber diameter
(2) Spherical particle diameter

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.

- *Provide the methodology used to estimate quantity and composition of latent debris.*
- *Provide the basis for assumptions used in the evaluation.*
- *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.*
- *Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris.*

PG&E Response:

- *Provide the methodology used to estimate quantity and composition of latent debris.*
- *Provide the basis for assumptions used in the evaluation.*
- *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.*

Latent debris has been evaluated via containment condition assessments. Containment walkdowns were completed for DCPP Unit 1 during the Fall 2005 1R13 outage. Containment walkdowns for DCPP Unit 2 will be completed during the Spring 2008, 2R14 outage. The Unit 1 walkdown was (and the Unit 2 walkdown will be) performed using guidance provided in NEI 02-01, "Condition Assessment Guidelines, Debris Sources inside Containment," Revision 1. The quantity and composition of the latent debris was evaluated by extensive sampling for latent debris (dust and lint) considering guidance in NEI 04-07 Volume 2.

Samples were taken to determine the latent debris mass distribution per unit area, referred to as latent debris density (e.g. lbm/1000 ft^2) of representative surfaces throughout containment including vertical surfaces such as the liner and walls. These debris densities were then applied to all of the representative surface areas inside containment to calculate the total amount of latent debris inside containment.

The latent debris density was estimated by weighing sample bags before and after sampling, dividing the net weight increase by the sampled surface area, adjusting the result based on an estimated sample efficiency, and converting the result to a density (e.g. lbm/1000 ft^2).

Twenty-nine samples were taken for Unit 1. The Unit 1 and Unit 2 physical configurations are similar, and the cleaning methodology and acceptance criteria are similar for both units. Therefore, the 29 samples taken are representative of both units.

Although the DCPP insulation is predominantly RMI, the statistical sample mass collection methodology (i.e., three samples from each category of surface) was not used. The loadings of latent debris have been observed to be both light and uniform in both DCPP Unit 1 and Unit 2. Many areas and surfaces cannot be reached for sampling without scaffolding or adding special provisions for fall protection devices. DCPP used an alternative approach to minimize personnel risk. Representative samples were taken from accessible surfaces. Visual observations of these sample locations were compared to visual observations of other surfaces and conservative estimates of bounding debris loadings were made. The data from Unit 1 was used to substantiate a common latent debris source term for both units.

The results of the latent debris calculation conservatively determined the debris loading to be less than 60 lbm in each containment. DCPP elected to use a conservative bounding value of 100 lbm for the latent debris source term in containment.

Visual examination of the debris showed very low fiber content. In lieu of analysis of samples, conservative values for debris composition properties were assumed as recommended by NEI 04-07 Volume 2. This results in a conservative estimate of fiber content. The particulate/fiber mix of the latent debris is assumed to be 15 percent fiber. The latent fiber debris is assumed to have a mean density of 94 lbm/ft3 (1.5 g/cm3) and the latent particulate debris is assumed to have a nominal density of 169 lbm/ft3 (2.7 g/cm3). The latent debris fiber bulk density is assumed to be the same as that of low-density fiberglass (LDFG) which is 2.4 lb/ft3. The characteristic size of the latent fiberglass is also assumed to be the same as LDFG or approximately 7 microns.

Fiber and particulate debris was observed in most areas of containment, but in varying quantities. Latent debris was primarily found to be particulate such as dirt and dust. Paint chips were found in some areas as were pieces of metal fragments and latex gloves. Several broken tie-wraps were found.

- *Provide amount of sacrificial strainer surface area allotted to miscellaneous debris.*

The containment condition assessments also included the identification of labels, tape, and tags. Qualified tags attached with stainless steel wires were found for much of the equipment. There were nonqualified labels, tape, and tags found inside containment, as well. Based upon walkdowns performed at DCPP Unit 2 during the Spring 2006 Unit 2 Thirteenth Refueling Outage (2R13), it was determined that there is approximately 206 ft^2 of miscellaneous debris (labels, tape, and tags) inside the crane wall. For conservatism, all of the miscellaneous debris inside the crane wall is assumed to be destroyed as fines in the range of 1/8-inch x 1/8-inch to 1/2-inch x 1/2-inch pieces, large enough to plug holes on the sump screen, but small enough to be readily transportable. Based on walkdowns performed at DCPP Unit 2 during 2R13, it was determined that there is approximately 15 ft^2 of miscellaneous debris outside the crane wall. Due to similarity, the values of miscellaneous debris for Unit 2 would also apply to Unit 1.

An appropriate sacrificial screen area was calculated for each limiting break case. Sacrificial screen area is calculated for the debris types which would directly block perforated plate holes. Sacrificial screen areas are break specific since debris transport fractions are different for Group 1 (Loops 1 and 2) and Group 2 (Loops 3 and 4) breaks, and some debris quantities are also break specific. Table 1 summarizes the constituents of sacrificial screen area and the calculated values for the four limiting break locations.

Miscellaneous debris is also discussed in more detail in Section 3e, Debris Transport.

Table 1

Debris Source	Area (ft^2)	Transport Fraction Group 1 (Group 2)	Sacrificial Area for Crossover Leg Break at RCP 4	Sacrificial Area for Crossover Leg Break at SG 2	Sacrificial Area for PZR RV Inlet Break	Sacrificial Area for PZR Surge Line Break
3M Foil Tape	370	2% (20%)	74.00 ft^2	7.40 ft^2	7.40 ft^2	7.40 ft^2
Vapor Barrier	Note 1	100% (100%)	19.50 ft^2	4.80 ft^2	7.15 ft^2	0.00 ft^2
Silicone Rubber (Flexicone sleeving)	Note 1	1% (1%)	0.00 ft^2	0.33 ft^2	0.00 ft^2	0.66 ft^2
Reflective Tape (outside crane wall)	Note 1	12% (10%)	0.45 ft^2	0.87 ft^2	0.00 ft^2	0.42 ft^2
Conduit Tape (outside crane wall)	Note 1	13% (41%)	0.00 ft^2	0.30 ft^2	0.00 ft^2	0.00 ft^2
Cable Ties (on PZR heater cables)	Note 1	32% (19%)	0.00 ft^2	0.06 ft^2	0.00 ft^2	0.06 ft^2
3M Arc Prevention Tape	Note 1	1% (1%)	0.00 ft^2	0.06 ft^2	0.00 ft^2	0.06 ft^2
Reflective Tape (inside crane wall)	116.1	3% (3%)	3.48 ft^2	3.48 ft^2	3.48 ft^2	3.48 ft^2
Black Lettering Tape (inside crane wall)	19.8	66% (61%)	12.08 ft^2	13.07 ft^2	13.07 ft^2	13.07 ft^2
Conduit Tape (inside crane wall)	21.3	46% (31%)	6.60 ft^2	9.80 ft^2	9.80 ft^2	9.80 ft^2
Lamicoids (inside crane wall)	7.2	28% (16%)	1.15 ft^2	2.02 ft^2	2.02 ft^2	2.02 ft^2
Electric Tape (inside crane wall)	10.7	66% (61%)	6.53 ft^2	7.06 ft^2	7.06 ft^2	7.06 ft^2
Stickers/Labels (inside crane wall)	20.3	69% (63%)	12.79 ft^2	14.01 ft^2	14.01 ft^2	14.01 ft^2
Cable Ties (inside crane wall)	4.8	32% (19%)	0.91 ft^2	1.54 ft^2	1.54 ft^2	1.54 ft^2
RP Survey Tags (inside crane wall)	5.5	3% (17%)	0.94 ft^2	0.17 ft^2	0.17 ft^2	0.17 ft^2
Stickers/Labels (outside crane wall)	15.1	53% (52%)	7.85 ft^2	8.00 ft^2	8.00 ft^2	8.00 ft^2
Operating Margin	50.0	-	50.00 ft^2	50.00 ft^2	50.00 ft^2	50.00 ft^2
TOTAL	-	-	**196.3 ft^2**	**123.0 ft^2**	**123.7 ft^2**	**117.8 ft^2**

Note 1 – Area destroyed is break specific

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.

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

PG&E Response:

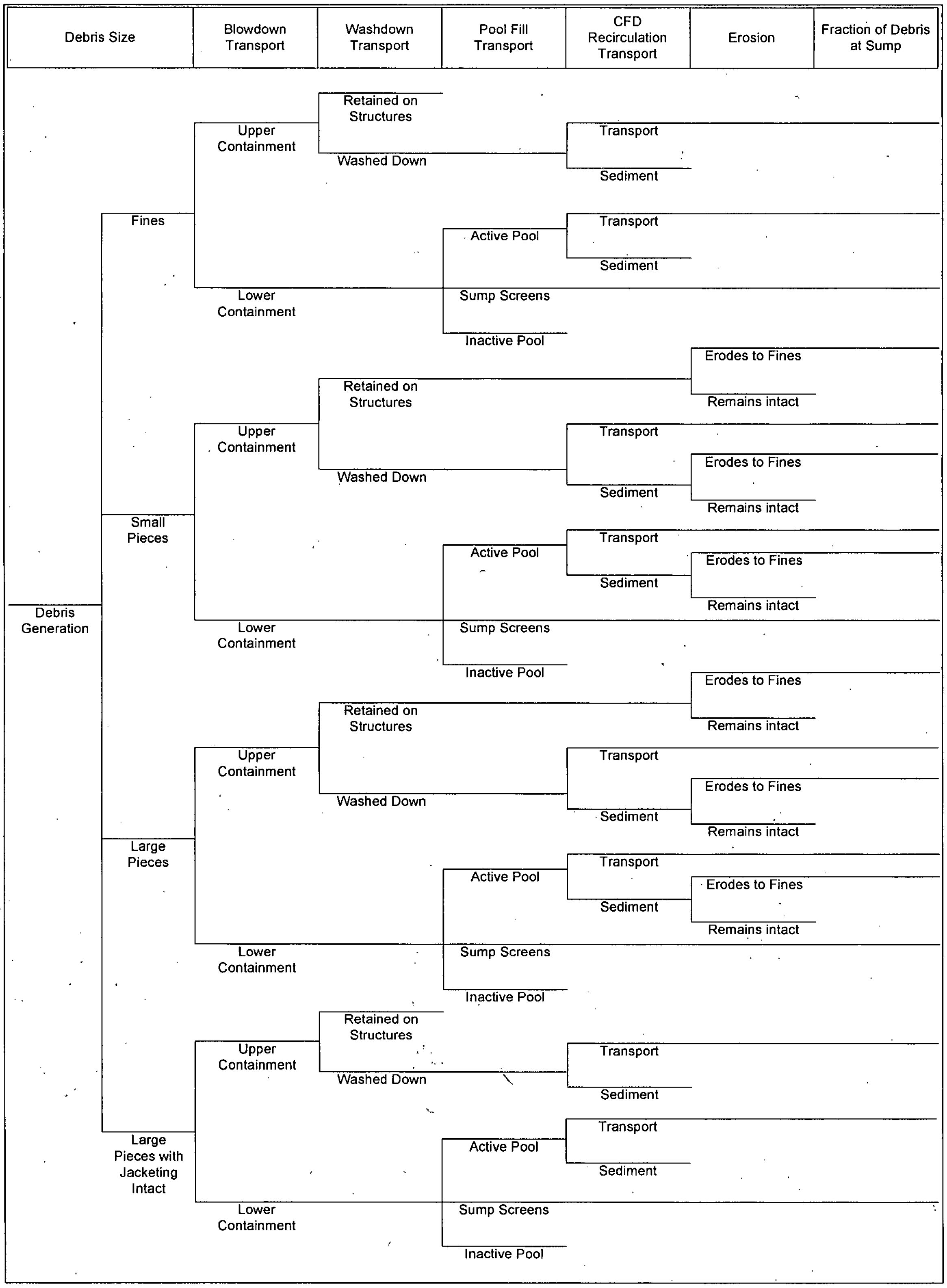
- *Describe the methodology used to analyze debris transport during the blowdown, washdown, pool fill-up, and recirculation phases of an accident.*

The methodology used in the transport analysis is based on the NEI 04-07, Volume 1, guidance for refined analyses as modified by the refined methodologies suggested in Appendices III, IV, and VI of NEI 04-07, Volume 2. The specific effect of each of four modes of transport was analyzed for each type of debris generated. These modes of transport are:

- Blowdown transport – the vertical and horizontal transport of debris to all areas of containment by the break jet;
- Washdown transport – the vertical (downward) transport of debris by the CS and break flows;
- Pool fill-up transport – the transport of debris by break and CS flows from the RWST to regions that may be active or inactive during recirculation; and
- Recirculation transport – the horizontal transport of debris from the active portions of the recirculation pool to the sump screens by the flow through the ECCS.

The logic tree approach was then applied for each type of debris determined from the debris generation calculation. The logic tree shown in the following diagram is somewhat different than the baseline logic tree provided in NEI 04-07, Volume 1. This departure was made to account for certain nonconservative assumptions identified in NEI 04-07, Volume 2, including the transport of large pieces, the potential for washdown debris to enter the pool after inactive areas have been filled, and the direct transport of debris to the sump screens during pool fill-up. Also, the generic logic tree was expanded to account for a more refined debris size distribution. Some branches of the logic tree may not be required for certain types of debris.

The following figure shows a generic transport logic tree.


Debris Size
Blowdown Transport
Washdown Transport
Pool Fill Transport
CFD Recirculation Transport
Erosion
Fraction of Debris at Sump
Debris Generation
Fines
Upper Containment
Retained on Structures
Washed Down
Transport
Sediment
Transport
Active Pool
Sediment
Lower Containment
Sump Screens
Inactive Pool
Small Pieces
Erodes to Fines
Retained on Structures
Remains intact
Upper Containment
Transport
Erodes to Fines
Washed Down
Sediment
Remains intact
Transport
Active Pool
Erodes to Fines
Sediment
Remains intact
Lower Containment
Sump Screens
Inactive Pool
Large Pieces
Erodes to Fines
Retained on Structures
Remains intact
Upper Containment
Transport
Erodes to Fines
Washed Down
Sediment
Remains intact
Transport
Active Pool
Erodes to Fines
Sediment
Remains intact
Lower Containment
Sump Screens
Inactive Pool
Large Pieces with Jacketing Intact
Retained on Structures
Upper Containment
Transport
Washed Down
Sediment
Transport
Active Pool
Sediment
Lower Containment
Sump Screens
Inactive Pool

The basic methodology used for the DCPP debris transport analysis is shown below:

1. Based on many of the containment building drawings, a three-dimensional model was constructed using CAD (Computer Aided Drafting) software.
2. Transport flow paths were determined using a review of drawings and the CAD model. Potential upstream blockage points including screens, fences, grating, drains, etc. that could lead to water holdup were addressed.
3. Debris types and size distributions were gathered from the debris generation calculation for each postulated break location.
4. The fraction of debris blown into upper containment was determined based on the relative volumes of upper and lower containment.
5. The quantity of debris washed down by spray flow was conservatively determined.
6. The quantity of debris transported to inactive areas or directly to the sump screen was calculated based on the volume of the inactive and sump cavities proportional to the total water volume at the time these cavities are filled.
7. Using conservative assumptions, the locations of each type/size of debris at the beginning of recirculation were determined.
8. A CFD (Computational Fluid Dynamics) model was developed to simulate the flow patterns that would occur during recirculation.
    a. The mesh in the CFD model was nodalized to sufficiently resolve the features of the CAD model, but still keep the cell count low enough for the simulation to run in a reasonable amount of time.
    b. The boundary conditions for the CFD model were set based on the configuration of DCPP during the recirculation phase.
    c. The CS flow was included in the CFD calculation with the appropriate flow rate and kinetic energy to accurately model the effects on the containment pool. In order to achieve steady-state conditions, this flow was removed from the model through the exposed area of the containment structures and equipment below the water level.
    d. At the postulated LOCA break location, a mass source was added to the model to introduce the appropriate flow rate and kinetic energy associated with the break flow.
    e. A negative mass source was added at the sump location with a total flow rate equal to the break flow.
    f. An appropriate turbulence model was selected for the CFD calculations.
    g. After running the CFD calculations, the mean kinetic energy was checked to verify that the model had been run long enough to reach steady-state conditions.
    h. Transport metrics were determined based on relevant tests and calculations for each significant debris type present in the DCPP containment building.
9. A graphical determination of the transport fractions of each type of debris was made using the velocity and turbulent kinetic energy (TKE) profiles from the CFD model output, along with the determined initial distribution of debris.
10. The recirculation transport fractions from the CFD analysis were gathered to input into the transport logic trees.
11. The effects of erosion on the LOCA generated debris were evaluated to determine the potential significance.
12. The overall transport fraction for each type of debris was determined by combining each of the previous steps in logic trees.

Blowdown Transport

The fraction of blowdown flow to various regions was estimated using the relative volumes of containment. Fine debris can be easily suspended and carried by the blowdown flow. Small and large piece debris can also be easily carried by the high velocity blowdown flow in the vicinity of the break. However, in areas farther away from the break that are not directly affected by the blowdown, this debris would likely fall to the floor.

The volumes for the upper containment (including the refueling canal and areas above the operating deck) and for lower containment (including the reactor cavity, the volume inside the crane wall, and all volume between the crane wall and the outer containment wall below the operating deck) were determined from the CAD model of the DCPP containment. Because the debris was assumed to be carried with the blowdown flow, the flow split is then proportional to the containment volumes. This results in a transport fraction for the fine and small debris to upper containment of 80 percent.

Additional guidance was incorporated into the analysis through use of the Boiling Water Reactor (BWR) Utility Resolution Guide (URG). The guidance from this document indicates that grating would trap approximately 65 percent of the small RMI debris blown toward it.

The following table shows the transport fractions for each type/size of debris to upper containment due to the blowdown forces for breaks inside the crane wall. Note that debris outside the ZOI (including latent dirt/dust and fibers) is not affected by blowdown, and therefore, the transport fraction for this debris would be 0 percent.

Blowdown transport fractions of debris to upper containment (all cases):

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI, 3M Foil Tape	NA	28%	0%	NA
Fiberglass Inside ZOI[1]	80%	NA	NA	NA
Fiberglass Outside ZOI[2]	0%	NA	NA	NA
Cal-Sil, Marinite and Mica Tape	80%	NA	NA	NA
Vapor Barrier	NA	28%	NA	NA
3M Arc Prevention Tape and Silicone Rubber (from Flexicone sleeving)	NA	28%	NA	NA
RTV Foam	NA	0%	NA	NA
Coatings Inside ZOI[3]	80%	NA	NA	NA
Coatings Outside ZOI[4]	0%	0%	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA
Miscellaneous Debris Inside ZOI[5]	NA	28%	NA	NA
Miscellaneous Debris Outside ZOI[6]	NA	0%	NA	NA

[1]Includes Temp-Mat, Kaowool, Mineral Wool, and pressurizer heater cable fiberglass (heater cables and Flexicone sleeving)
[2]Includes Temp-Mat, Kaowool and Cerablanket
[3]Includes Ameron 66, IOZ, Epoxy, and Aluminum
[4]Includes Alkyds, IOZ, and Aluminum
[5]Includes cable ties, light bulbs, reflective tape, conduit tape, black lettering tape, lamicoids, electric tape, stickers/labels, and RP survey tags
[6]Includes stickers/labels

Washdown Transport

During the washdown phase, debris in upper containment can be washed down by CS. Since all of the debris blown to upper containment was determined to be fines and small pieces, it was conservatively assumed that all of this debris would be washed back to lower containment with the exception of any small piece debris held up on grating as it is washed back down.

Because the majority of debris blown to upper containment will land on the operating deck or in the refueling canal, the quantity of debris washed to specific locations was determined using an analysis of the spray flow to these areas. This results in a washdown split of 86 percent to the annulus and 14 percent to the refueling canal.

Credit was also taken for holdup of RMI on grating. The BWR URG indicates that the retention of small RMI debris on gratings is approximately 29 percent. Therefore, the washdown transport fraction for small RMI to the annulus was determined to be 64 percent. No credit was taken for the holdup of miscellaneous debris in upper containment.

Washdown transport fractions of debris from upper containment to the annulus:

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI, 3M Foil Tape	NA	64%	NA	NA
Fiberglass Inside ZOI	86%	NA	NA	NA
Fiberglass Outside ZOI	NA	NA	NA	NA
Cal-Sil, Marinite and Mica Tape	86%	NA	NA	NA
Vapor Barrier	NA	86%	NA	NA
3M Arc Prevention Tape and Silicone Rubber (from Flexicone sleeving)	NA	86%	NA	NA
RTV Foam	NA	NA	NA	NA
Coatings Inside ZOI	86%	NA	NA	NA
Coatings Outside ZOI	NA	86%	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA
Miscellaneous Debris Inside ZOI	NA	86%	NA	NA
Miscellaneous Debris Outside ZOI	NA	NA	NA	NA

Washdown transport fractions of debris from upper containment to the refueling canal drain discharge:

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI, 3M Foil Tape	NA	14%	NA	NA
Fiberglass Inside ZOI	14%	NA	NA	NA
Fiberglass Outside ZOI	NA	NA	NA	NA
Cal-Sil, Marinite and Mica Tape	14%	NA	NA	NA
Vapor Barrier	NA	14%	NA	NA
3M Arc Prevention Tape and Silicone Rubber (from Flexicone sleeving)	NA	14%	NA	NA
RTV Foam	NA	NA	NA	NA
Coatings Inside ZOI	14%	NA	NA	NA
Coatings Outside ZOI	NA	14%	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA
Miscellaneous Debris Inside ZOI	NA	14%	NA	NA
Miscellaneous Debris Outside ZOI	NA	NA	NA	NA

Pool Fill-Up Transport

During pool fill-up, the flow of water transports insulation debris from the break location to all areas of the recirculation pool. Some of the debris was assumed to transport to inactive areas of the pool including some transport directly to the sump screens as the emergency sump cavity is filled.

Assuming that fine debris is uniformly distributed in the pool, and the water entering the pool from the break and sprays is clean (i.e. washdown of debris in upper containment occurs after inactive cavities have been filled), the transport to each of the inactive cavities was calculated for DCPP (note that the assumption that debris washdown occurs after inactive cavities have been filled is consistent with the requirements of NEI 04-07, Volume 2, Section 3.8).

Pool fill-up transport fractions of debris to inactive areas:

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI, 3M Foil Tape	NA	15%	15%	NA
Fiberglass Inside ZOI	15%	NA	NA	NA
Fiberglass Outside ZOI	0%	NA	NA	NA
Cal-Sil, Marinite and Mica Tape	15%	NA	NA	NA
Vapor Barrier	NA	0%	NA	NA
3M Arc Prevention Tape and Silicone Rubber (from Flexicone sleeving)	NA	15%	NA	NA
RTV Foam	NA	0%	NA	NA
Coatings Inside ZOI	15%	NA	NA	NA
Coatings Outside ZOI	0%	0%	NA	NA
Dirt/Dust	15%	NA	NA	NA
Latent Fiber	15%	NA	NA	NA
Miscellaneous Debris Inside ZOI	NA	15%	NA	NA
Miscellaneous Debris Outside ZOI	NA	0%	NA	NA

Pool fill-up transport fractions of debris to sump screen:

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI, 3M Foil Tape	NA	0%	0%	NA
Fiberglass Inside ZOI	9%	NA	NA	NA
Fiberglass Outside ZOI	0%	NA	NA	NA
Cal-Sil, Marinite and Mica Tape	9%	NA	NA	NA
Vapor Barrier	NA	0%	NA	NA
3M Arc Prevention Tape and Silicone Rubber (from Flexicone sleeving)	NA	0%	NA	NA
RTV Foam	NA	0%	NA	NA
Coatings Inside ZOI	9%	NA	NA	NA
Coatings Outside ZOI	0%	0%	NA	NA
Dirt/Dust	9%	NA	NA	NA
Latent Fiber	9%	NA	NA	NA
Miscellaneous Debris Inside ZOI	NA	0%	NA	NA
Miscellaneous Debris Outside ZOI	NA	0%	NA	NA

- *Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results.*

Recirculation Transport Using CFD

The recirculation pool debris transport fractions were determined through CFD modeling using Flow-3D. To accomplish this, a three-dimensional CAD model was imported into the CFD model. Flows into and out of the pool were defined, and the CFD simulation was run until steady-state conditions were reached. The result of the CFD analysis is a three-dimensional model showing the turbulence and fluid velocities within the recirculation pool. By comparing the direction of pool flow, the magnitude of the turbulence and velocity, the initial location of debris, and the specific debris transport metrics (i.e. the minimum velocity or turbulence required to transport a particular type/size of debris), the recirculation transport of each type/size of debris to the sump screens was determined.

The significant parts of the CFD model are shown in Figure 1. The sump mass sink, the Loop 2 and Loop 3 break locations, and the modeled spray drainage are highlighted.

Computational Mesh

A rectangular mesh was defined in the CFD model that was fine enough to resolve important features, but not so fine that the simulation would take prohibitively long to run. A 6-inch cell length was chosen as the largest cell size that could reasonably resolve the concrete structures that compose the containment floor. For the cells right above the containment floor, the mesh was set to 3-inches tall in order to closely resolve the vicinity of settled debris. To further define specific objects, node planes were placed at the edges of key structures including the top of the sump curb, and the edges of the break and spray mass source obstacles. The total cell count in the model was 630,000, a satisfactory compromise between model run-time and model resolution.

Boundary Conditions

Boundary conditions for the CFD were set at the minimum and maximum of the x, y, and z planes. The minimum z boundary condition and the minimum and maximum x and y boundary conditions are irrelevant since the solid containment building wall acts as a boundary to flow. The maximum z condition (above the water level) was set as a specified pressure boundary with a null value as the reference pressure for the calculation (note that fluid properties and flow conditions in the containment pool are insensitive to pressure).

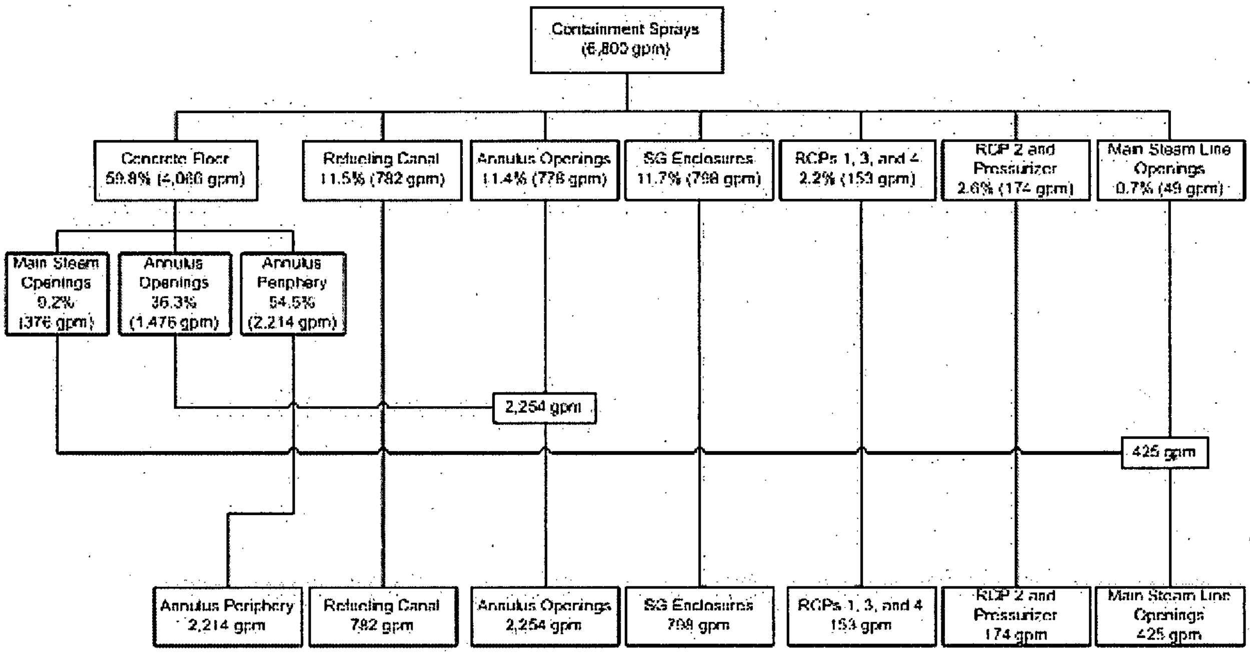
In the CFD model, the containment structures (including walls, floors, and structural steel) are specified as having smooth surfaces. Sensitivity calculations have shown little dependence of containment pool velocity on surface roughness within the variability between bare and painted concrete and steel (the tortuosity of the containment floor is what matters). Therefore, negligible differences in debris transport predictions would result between a CFD calculation performed with smooth surfaces and one performed with the actual roughness of surfaces.

Modeling of CS Flows

From consideration of various plan and section drawings, as well as the containment building CAD model, it was judged that spray water would drain to the pool through numerous pathways. Some of these pathways included, but were not limited to, the open gaps in the SG penetrations through the operating deck, the RCP hatches, the 8-inch refueling canal drain line, grating above the containment annulus, and the annulus periphery.

Assuming that spray flow is uniform across containment, the fraction of spray landing on any given area was calculated using the ratio of that area to the overall area. Also, for sprays landing on a solid surface, such as the operating deck, the runoff flow split to different regions (such as the annulus) was approximated using the ratios of open perimeters where water could drain.

The following figure is the CS drainage flowchart.



When introducing the SG compartment and annulus spray drainage to the containment pool model, simplifications had to be made due to the infeasibility of modeling all the individual water droplets/streams that would fall into the pool. Although modeling individual water droplets is within the capability of Flow-3D, the simultaneous modeling of the overwhelming number of droplets that would be falling into the containment pool is not. Accordingly, the introduction of the spray drainage to the model was accomplished as follows:

- The kinetic energy of the falling droplets and streams was accounted for through a consideration of the first law of thermodynamics (conservation of energy).
- At DCPP, the farthest distance that spray water would fall before hitting the pool is approximately 46 feet (the difference between the 93.8 ft water level elevation and the grating at the 140.0 ft elevation). This gives a freefall velocity of 54 ft/s. However, the terminal velocity of a large raindrop is only 29 ft/s. Therefore, a velocity of 29 ft/s was used to calculate the kinetic energy imparted to the pool. This is conservative since smaller drops have a lower terminal velocity.
- The kinetic energy from the spray drainage was introduced to the CFD model near the surface of the pool.
- Since the CS pumps are drawing down the RWST, the addition of this flow creates a transient condition (raising the water level). In order to attain a steady-state solution, however, the water level must remain constant. Therefore, a flow equal to the total spray flow (6,800 gpm) was drawn out of the model through the exposed area of the equipment and concrete below the water level. This enables the CFD calculation to reach steady-state, and has minimal effect on the pool given the large surface area that is used to draw out the water.

To accomplish this, various regions were defined (around the annulus periphery, below the annulus grated openings, around the SG support structures, around the RCP 1, 3, and 4 support structures, around the RCP 2 support structure, below the main steam line openings, and below the refueling canal drain) and populated with discrete mass source particles. The appropriate flow rate and velocity was set for the sprays in each of these regions.

Modeling of Break Flow

The water stream falling from the postulated break would introduce momentum into the containment pool that would influence the flow dynamics. This break stream momentum is accounted for by introducing the break flow to the pool at the velocity a freefalling object would have if it fell the vertical distance from the location of the break to the surface of the pool.

The center of the reactor inlet nozzle (approximately the same elevation as the postulated break) is at an elevation of 107.0 ft. Since the floor level is at elevation 91.0 ft and the water level is 2.8 ft, this gives a total freefall distance from the break to the surface of the pool of 13.2 ft, which corresponds to a freefall velocity of 29.2 ft/s.

The horizontal component of the break flow is not included in the velocity introduced in the CFD model. This is acceptable because it is a very small portion of the overall velocity when compared with the vertical freefall component. Additionally, the break flow is very likely to hit obstacles in containment as it falls, which would dissipate energy. The slight increase in the break velocity if the horizontal component were included would likely be offset by the decrease in energy caused by obstacles which would tend to break up the break flow as it falls. Therefore, it is considered acceptable to introduce the break flow at a velocity equal to its freefall velocity.

Containment Recirculation Sump

The containment recirculation sump at DCPP includes front and rear strainers and is located in the containment annulus. The strainer assembly consists of vertically oriented perforated plates, water collection plenums and a vortex suppressor. A trash rack with an integral debris curb is positioned in front of the strainers. The sump has two suction pipes, which feed the two RHR trains. The mass sink used to pull flow from the CFD model was defined above the two pipes. The modeled flow through the sump consisted only of the break flow since the spray pumps would be shut off after the RWST has been drawn down.

A negative flow rate of 7769 gpm was set for the sump mass sink. This directs the CFD model to draw out the specified amount of water from the pool over the entire exposed surface area of the mass sink obstacle.

The detailed structure of the grating and screen was not included in the CFD model since the components of this structure are too small to be resolved. However, a porous object was placed in front of the sump, with the porosity in the x and z directions set to 0.9, and the porosity in the y direction set to 0. This limits the flow to the x and z directions as it enters the sump, similar to the effects that the grating and screen would have.

Turbulence Modeling

Several different turbulence modeling approaches can be selected for a Flow-3D calculation. The approaches are (ranging from least to most sophisticated):

- Prandtl mixing length
- Turbulent energy model
- Two-equation k-ε model
- Renormalized group theory (RNG) model
- Large eddy simulation model

The RNG turbulence model was judged to be the most appropriate for this CFD analysis due to the large spectrum of length scales that would likely exist in a containment pool during emergency recirculation. The RNG approach applies statistical methods in a derivation of the averaged equations for turbulence quantities (such as turbulent kinetic energy and its dissipation rate). RNG-based turbulence schemes rely less on empirical constants while setting a framework for the derivation of a range of models at different scales.

Steady State Metrics

The CFD model was started from a stagnant state at a pool depth of 2.8 ft, and run long enough for steady-state conditions to develop. The model was run for slightly longer than 200 seconds of real time for both the Loop 2 and Loop 3 break cases. All of the velocity and TKE results presented reflect steady-state conditions.

Debris Transport Metrics

Metrics for predicting debris transport have been adopted or derived from data. The specific metrics are the TKE necessary to keep debris suspended, and the flow velocity necessary to tumble sunken debris along a floor. The metrics utilized in the DCPP transport analysis originate from either: (a) NUREG/CR-6772 Table 3.5, (b) NUREG/CR-6808 Figure 5-2, (c) calculated using Stokes' Law using saturated water properties at 215°F, or (d) from DCPP specific testing.

Table 1 summarizes the debris settling and tumbling transport metrics.

Graphical Determination of Debris Transport Fractions

The following steps were taken to determine what percentage of a particular type of debris could be expected to transport through the containment pool to the emergency sump screens.

- Colored contour velocity and TKE maps indicating regions of the pool through which a particular type of debris could be expected to transport were generated from the Flow-3D results in the form of bitmap files.
- The bitmap files were overlaid on the initial debris distribution plots and imported into AutoCAD with the appropriate scaling factor to convert the length scale of the color maps to feet.
- For the uniformly distributed debris, closed polylines were drawn around the contiguous areas where velocity or TKE was high enough that debris could be carried in suspension or tumbled along the floor to the sump screens.
- The areas within the closed polylines were determined utilizing an AutoCAD querying feature.
- The combined area within the polylines was compared to the debris distribution area.

- The percentage of a particular debris type that would transport to the sump screens was estimated based upon the above comparison.

Plots showing the TKE and the velocity magnitude in the pool were generated for each case to determine areas where specific types of debris would be transported. The limits on the plots were set according to the minimum TKE or velocity metrics necessary to move each type of debris. Regions where the debris would be suspended were specifically identified in the plots as well as regions where the debris would be tumbled along the floor. Color coding TKE portions of the plots is a three-dimensional representation of the TKE. The velocity portion of the plots represents the velocity magnitude just above the floor level (1.5 inches), where tumbling of sunken debris could occur. Directional flow vectors were also included in the plots to determine whether debris in certain areas would be transported to the sump screens or transported to quieter regions of the pool where it could settle to the floor.

Sample Transport Analysis for Small Piece Stainless Steel RMI

Turbulence in the pool is not high enough to suspend small RMI debris except in the vicinity of the break location. Since the small pieces of RMI would settle in most of the pool, the tumbling velocity is the predominant means of transport.

The turbulence inside the crane wall near the debris interceptors is not high enough to suspend small pieces of RMI debris. Since the RMI debris located inside the crane wall represents the debris not blown to upper containment, the recirculation transport fraction of small RMI for this case is zero percent.

The small RMI debris washed down from upper containment was assumed to be distributed uniformly in the containment annulus. The annulus washdown area was overlaid on top of the plot showing tumbling velocity and flow velocity vectors to determine the recirculation transport fraction. The area where small pieces of RMI would transport within the initial distribution area is 460 ft^2. Since the initial distribution area in the annulus was determined to be 4,710 ft^2, the recirculation transport fraction for small pieces of the annulus washdown RMI is 10 percent.

Figure 2 shows TKE and velocity with limits set at suspension/tumbling of small pieces of stainless steel RMI (for a Loop 2 break).

Figure 3 shows the distribution of small piece RMI washed down from upper containment.

Figure 4 shows the floor area where small RMI washed down into the containment annulus would transport to the sump (for a Loop 2 break).

Debris Erosion in the Recirculation Pool

All fibrous, calcium silicate, and marinite debris is generated as 100 percent fines, which do not further erode in the pool. Coatings chips and miscellaneous debris (generated as small pieces) also do not further erode in the pool. RMI and 3M foil tape debris are metallic and are therefore, assumed to not erode in the recirculation pool.

- *State whether fine debris was assumed to settle and provide basis for any settling credited.*

Because of the very low turbulence required to keep fine material suspended, the CFD shows that this debris will not settle in the recirculation pool. Complete suspension of this debris results in 100 percent transport (accept for debris entering inactive areas).

- *Provide a summary of, and supporting basis for, any credit taken for debris interceptors.*

As part of DCPP's debris reduction modifications, debris interceptors were installed in all three crane wall doors. These debris interceptors are vertically mounted perforated stainless steel plates (18-inches tall, 11 gauge, with 1/8-inch diameter holes) with a horizontal lip (10 inches, also perforated stainless steel plate) that projects into the flow.

DCPP has performed testing to demonstrate the performance of the debris interceptors at the PG&E Applied Technology Services (ATS) testing facilities in San Ramon, California. This testing was performed under the ATS quality program using ATS test procedures. As was shown in testing, debris which transports to the debris interceptor by tumbling along the floor will be stopped by the interceptor. Debris which is suspended near the debris interceptor is assumed to transport over the interceptor, with the exception of paint chips.

DCPP performed specific debris interceptor testing to quantify the capture of suspended paint chips. This testing replicated an accurate RMI debris bed in front of the interceptor, and suspended 9-mil unqualified coatings chips and 2-mil high heat aluminum chips (in separate tests) uniformly throughout the flow stream. The test showed that the debris interceptor is effective in capturing 65 percent of 9-mil coatings chips and 22 percent of 2-mil coatings chips, even with sufficient TKE to suspend them at the interceptor.

- *Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance.*

DCPP has not utilized any assumptions or methods for debris transport that deviate from the approved guidance.

- *Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers.*

Table 2 shows the calculated debris transport fractions. Tables 3 through 6 show the transported debris quantities for the four limiting break locations.

Figure 1 – DCPP CFD Model Diagram (Unit 1)

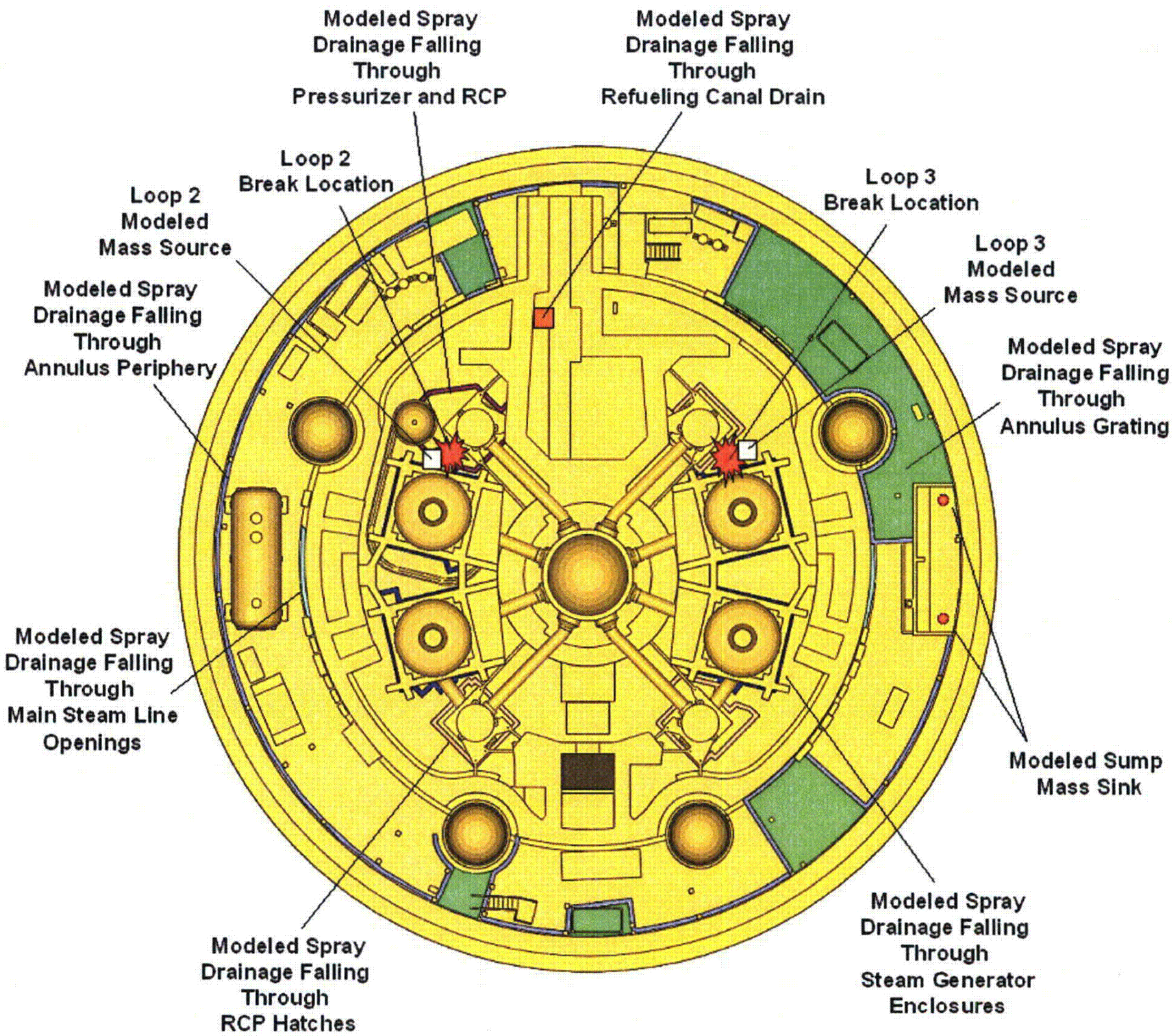


Figure 2 - TKE and Velocity with Limits Set at Suspension/Tumbling of Small Pieces of Stainless Steel RMI (For A Loop 2 break).

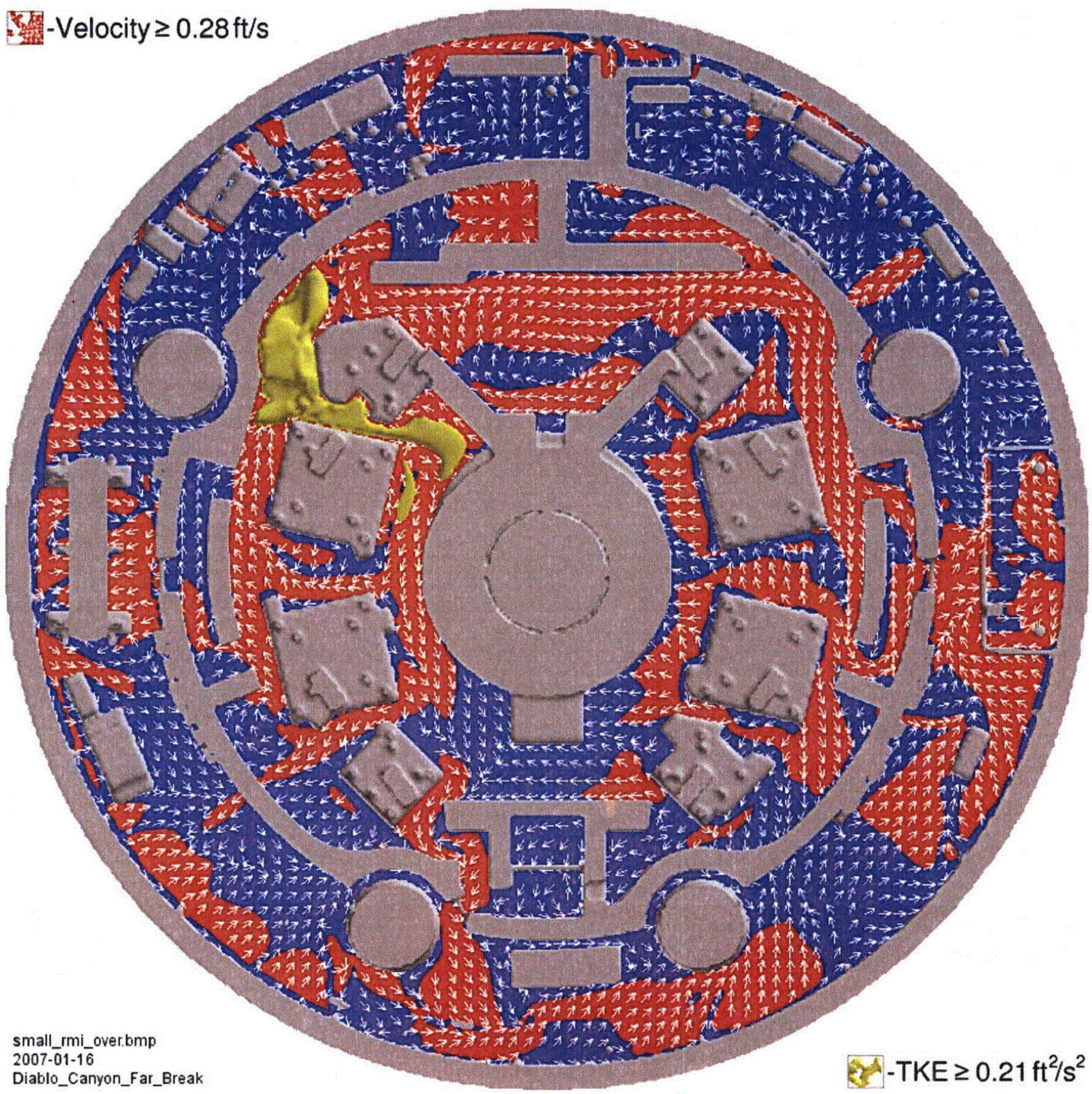


Figure 3 - Distribution of Small Piece RMI Washed Down from Upper Containment

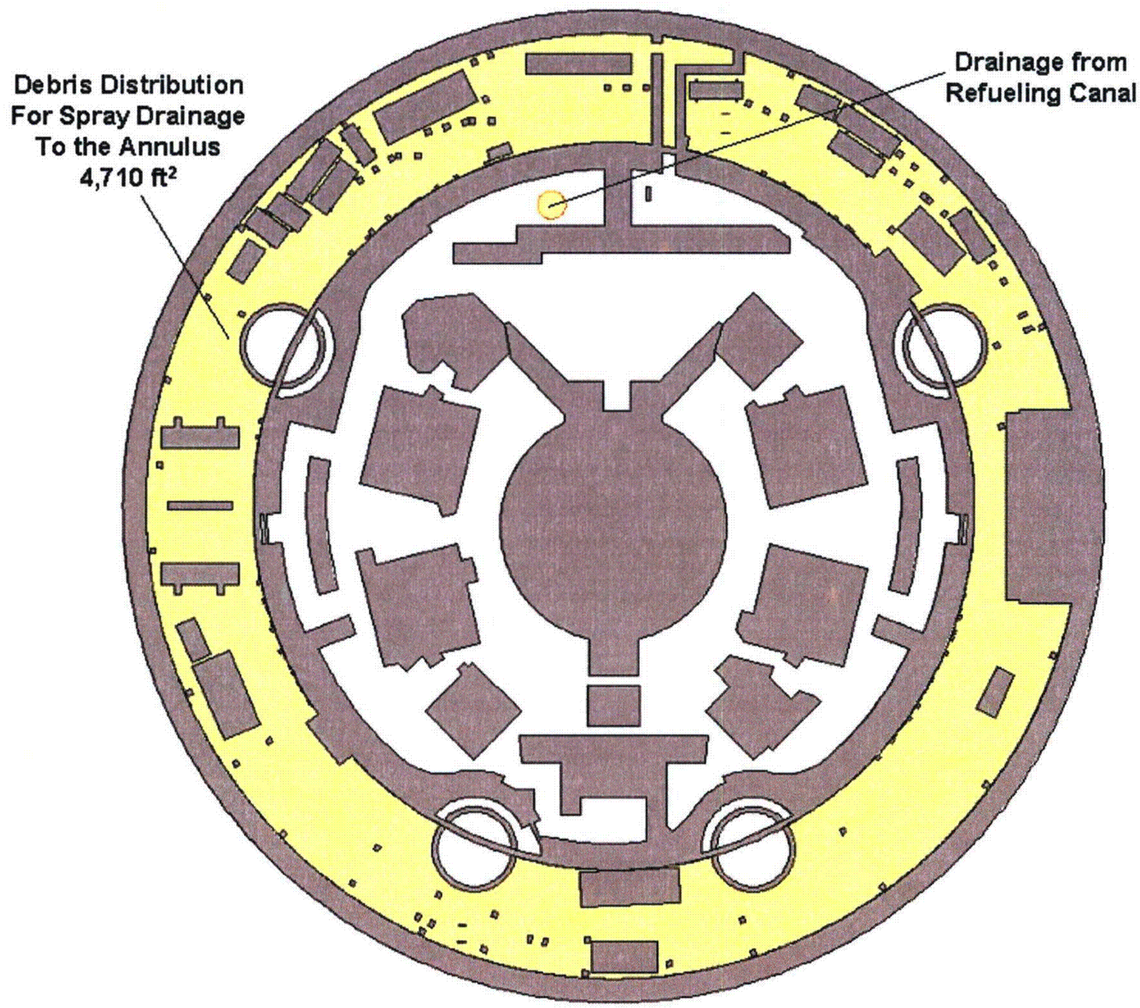


Figure 4 - Floor Area Where Small RMI Washed Down Into The Containment Annulus Would Transport To The Sump (For A Loop 2 Break).

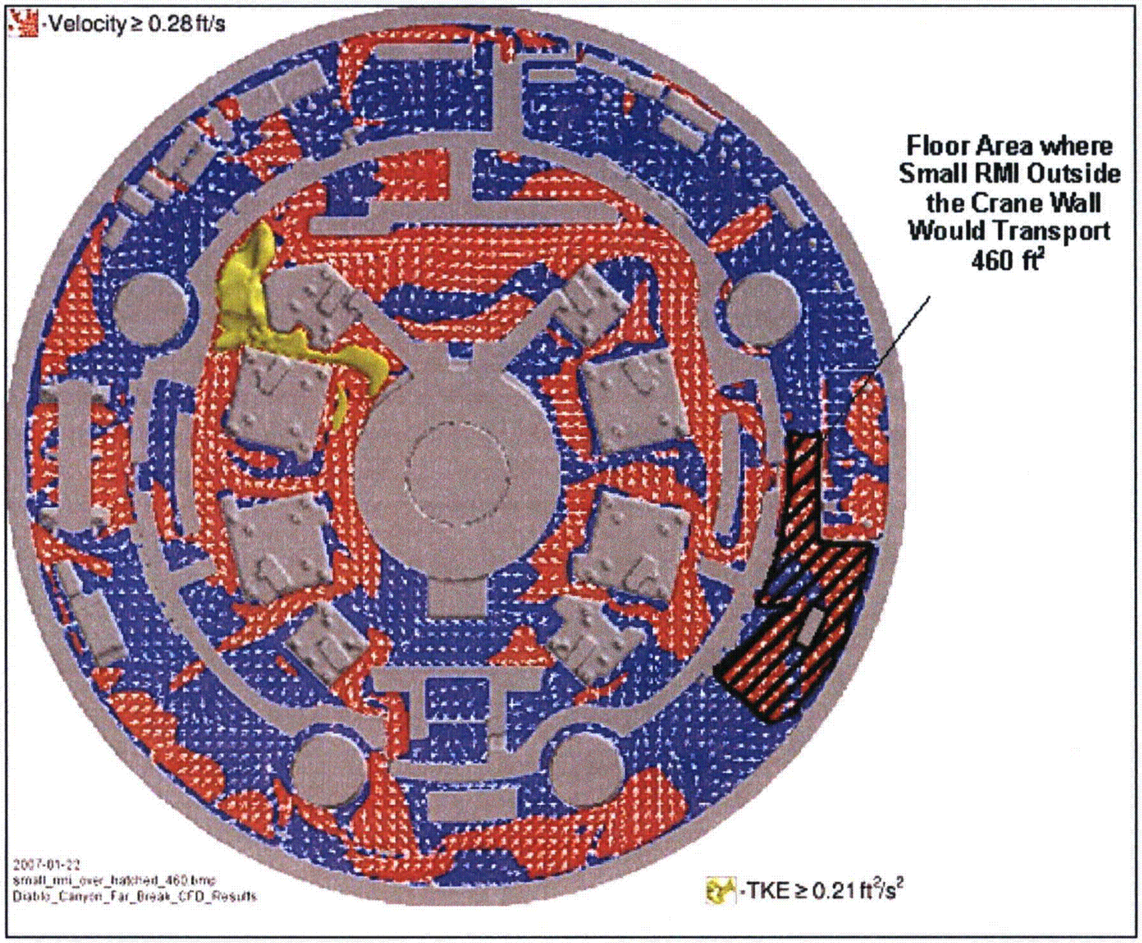


Table 1 – Debris Settling and Tumbling Transport Metrics

Debris Type	Size	Terminal Settling Velocity (ft/s)	Reference	Calculated Minimum TKE Required to Suspend (ft^2/sec^2)	Flow Velocity Associated with Incipient Tumbling (ft/s)	Reference
Stainless Steel RMI	Small Pieces (<4")	0.37[1]	NUREG/CR-6772 Table 3.5	0.21	0.28	NUREG/CR-6772 Table 3.5
	Large Pieces (>4")	0.48[1]	NUREG/CR-6772 Table 3.5	0.35	0.28	NUREG/CR-6772 Table 3.5
Temp-Mat, Kaowool, Mineral Wool, Cerablanket, Latent Fiber	Individual Fibers	0.0074	NUREG/CR-6808, Fig. 5-2	8.2E-05	NA	-
Cal-Sil	5-micron (144 lb/ft^3)	1.1E-04	Calculated per Stokes' law	1.7E-08	NA	-
Marinite	5-micron (144 lb/ft^3)	1.1E-04	Calculated per Stokes' law	1.7E-08	NA	-
3M Foil Tape	Small Pieces (1/8" to 1/2")	0.153	DCPP Test Report	3.51E-02	0.28	DCPP Test Report
Silicone Rubber (Flexicone Sleeving)	Small Pieces (1/8" to 1/2")	0.256	DCPP Test Report	0.098	0.372	DCPP Test Report
3M Arc Prevention Tape	Small Pieces (1/8" to 1/2")	0.192	DCPP Test Report	0.055	0.454	DCPP Test Report
Light Bulbs	Small Pieces (1/8" to 1/2")	0.359	DCPP Test Report	0.193	0.606	DCPP Test Report
Reflective Tape	Small Pieces (1/8" to 1/2")	0.181	DCPP Test Report	4.91E-02	0.235	DCPP Test Report
Conduit Tape	Small Pieces (1/8" to 1/2")	0.090	DCPP Test Report	1.22E-02	0.188	DCPP Test Report
Black Lettering Tape, Electrical Tape	Small Pieces (1/8" to 1/2")	0.057	DCPP Test Report	4.87E-03	0.185	DCPP Test Report
Lamicoids	Small Pieces (1/8" to 1/2")	0.125	DCPP Test Report	2.34E-02	0.397	DCPP Test Report
Stickers/Labels	Small Pieces (1/8" to 1/2")	0.061	DCPP Test Report	5.58E-03	0.185	DCPP Test Report
Cable Ties	Small Pieces (1/8" to 1/2")	0.120	DCPP Test Report	2.16E-02	0.313	DCPP Test Report
RP Survey Tags	Small Pieces (1/8" to 1/2")	0.138	DCPP Test Report	2.86E-02	0.292	DCPP Test Report
Qualified Epoxy	10-micron (105 lbm/ft^3)	2.2E-04	Calculated per Stokes' law	7.4E-08	NA	-
Qualified IOZ	10-micron (223 lbm/ft^3)	8.3E-04	Calculated per Stokes' law	1.0E-06	NA	-
Qualified Ameron 66	10-micron (97 lbm/ft^3)	1.8E-04	Calculated per Stokes' law	4.9E-08	NA	-

Table 1 – Debris Settling and Tumbling Transport Metrics (Con't)

Debris Type	Size	Terminal Settling Velocity (ft/s)	Reference	Calculated Minimum TKE Required to Suspend (ft^2/sec^2)	Flow Velocity Associated with Incipient Tumbling (ft/s)	Reference
Unqualified Alkyd	9-mil chips (105 lbm/ft^3)	0.10	DCPP Test Report	1.5E-02	0.34	DCPP Test Report
Unqualified IOZ	10-micron (223 lbm/ft^3)	8.3E-04	Calculated per Stokes' law	1.0E-06	NA	-
Unqualified Aluminum	10-micron (100 lbm/ft^3)	2.0E-04	Calculated per Stokes' law	5.8E-08	NA	
Unqualified Aluminum	2-mil chips (100 lbm/ft^3)	0.061	DCPP Test Report	5.58E-03	0.213	DCPP Test Report
Dirt/Dust	17.3-micron (169 lbm/ft^3)	1.7E-03	Calculated per Stokes' law	4.1E-06	NA	-

[1]Metrics are for 1/2 inch square crumpled foils for small RMI and 2 inch square crumpled foils for large RMI.

Table 2 – Debris Transport Fractions

Debris Type	Debris Size	Group 1 (Loop 2 Break CFD)	Group 2 (Loop 3 Break CFD)
Stainless Steel RMI	Small	2%	2%
	Large	0%	0%
3M Foil Tape	Small	2%	20%
Temp-Mat	Fines	97%	97%
Cal-Sil	Fines	97%	97%
Kaowool Blanket	Fines	97%	97%
Kaowool M Board	Fines	97%	97%
Marinite M Board	Fines	97%	97%
Mineral Wool on Pipe Fittings	Fines	97%	97%
Vapor Barrier Material	Small	100%	100%
RTV Foam	Small	100%	100%
Fiberglass (Heater Cable)	Fines	97%	97%
Fiberglass (Flexicone Sleeve)	Fines	97%	97%
Silicone Rubber (Flexicone Sleeving)	Fines	1%	1%
Mica Tape (Heater Cables)	Fines	97%	97%
3M Arc Prevention Tape	Fines	1%	1%
Light Bulbs	Small	0%	0%
Reflective Tape (Outside Crane Wall)	Small	12%	10%
Conduit Tape (Outside Crane Wall)	Small	13%	41%
Temp-Mat (Outside ZOI)	Fines	100%	100%
Cerablanket (Outside ZOI)	Fines	100%	100%
Fire Stop Kaowool (Outside ZOI)	Fines	100%	100%
Qualified Ameron 66 (Inside ZOI)	Fines	97%	97%
Qualified IOZ (Inside ZOI)	Fines	97%	97%
Qualified Epoxy (Inside ZOI)	Fines	97%	97%
Unqualified Alkyd (9-mil Chips)	Small	7.7%	6.7%
Unqualified IOZ	Fines	100%	100%
Unqualified Aluminum on Pressurizer	Fines	100%	100%
Unqualified Aluminum (2-mil Chips)	Small	78%	78%
Dirt/Dust	Fines	85%	85%
Latent Fiber	Fines	85%	85%
Reflective Tape (Inside Crane Wall)	Small	3%	3%
Black Lettering Tape (Inside Crane Wall)	Small	66%	61%
Conduit Tape (Inside Crane Wall)	Small	46%	31%
Lamicoids (Inside Crane Wall)	Small	28%	16%
Electric Tape (Inside Crane Wall)	Small	66%	61%
Stickers/Labels (Inside Crane Wall)	Small	69%	63%

Table 2 – Debris Transport Fractions (Con't)

Debris Type	Debris Size	Group 1 (Loop 2 Break CFD)	Group 2 (Loop 3 Break CFD)
Cable Ties (Inside Crane Wall)	Small	32%	19%
RP Survey Tags (Inside Crane Wall)	Small	3%	17%
Stickers/Labels (Outside Crane Wall)	Small	53%	52%

Table 3 - Transported Debris for Crossover Leg Break at Reactor Coolant Pump 4 Nozzle

Inside ZOI		Crossover Leg Break at RCP 4 Nozzle								Transported Debris					
Debris Type	Debris Size	Unit 1 Debris Quantity				Unit 2 Debris Quantity				Unit 1			Unit 2		
Stainless Steel RMI	Small Pieces (<4")	21,700	ft^2	-		21,700	ft^2	-		2%	434	ft^2	2%	434	ft^2
	Large Pieces (>4")	7,240	ft^2	-		7,240	ft^2	-		0%	0	ft^2	0%	0	ft^2
3M Foil Tape	Small Pieces (<4")	370	ft^2	-		370	ft^2	-		20%	74.00	ft^2	20%	74.00	ft^2
Temp-Mat	Fines	0.00	ft^3	0.00	lb.	0.12	ft^3	1.37	lb.	97%	0.00	lb.	97%	1.33	lb.
Cal-Sil	Fines	4.16	ft^3	60.32	lb.	4.16	ft^3	60.32	lb.	97%	58.51	lb.	97%	58.51	lb.
Kaowool Blanket	Fines	0.10	ft^3	0.60	lb.	0.10	ft^3	0.60	lb.	97%	0.58	lb.	97%	0.58	lb.
Kaowool M Board	Fines	0.64	ft^3	10.88	lb.	0.64	ft^3	10.88	lb.	97%	10.55	lb.	97%	10.55	lb.
Marinite M Board	Fines	0.74	ft^3	34.04	lb.	0.74	ft^3	34.04	lb.	97%	33.02	lb.	97%	33.02	lb.
Mineral Wool in Pipe Fittings	Fines	1.93	ft^3	15.44	lb.	1.93	ft^3	15.44	lb.	97%	14.98	lb.	97%	14.98	lb.
Vapor Barrier Material	1/8" to 1/2" pieces	19.50	ft^2	-		19.50	ft^2	-		100%	19.50	ft^2	100%	19.50	ft^2
RTV Foam	1/8" to 1/2" pieces	3.60	ft^3	67.32	lb.	3.60	ft^3	67.32	lb.	100%	67.32	lb.	100%	67.32	lb.
Light Bulbs	1/8" to 1/2" pieces	133.00	ft^2	-		133.00	ft^2	-		0%	0.00	ft^2	0%	0.00	ft^2
Reflective Tape (Outside Crane Wall)	1/8" to 1/2" pieces	4.50	ft^2	-		4.50	ft^2	-		10%	0.45	ft^2	10%	0.45	ft^2
Conduit Tape (Outside Crane Wall)	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-		41%	0.00	ft^2	41%	0.00	ft^2
Fiberglass (PZR Heater Cables)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Fiberglass (Flexicone Sleeving)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Silicone Rubber (Flexicone Sleeving)	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-		1%	0.00	ft^2	1%	0.00	ft^2
Mica Tape (PZR Heater Cables)	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
3M Arc Prevention Tape	1/8" to 1/2" pieces	0.00	ft^2	-		0.00	ft^2	-		1%	0.00	ft^2	1%	0.00	ft^2
Cable Ties	Fines	0.00	ft^2	-		0.00	ft^2	-		19%	0.00	ft^2	19%	0.00	ft^2
Qualified Ameron 66	Fines	0.18	ft^3	17.80	lb.	0.18	ft^3	17.80	lb.	97%	17.27	lb.	97%	17.27	lb.
Qualified CZ-11	Fines	0.24	ft^3	53.70	lb.	0.24	ft^3	53.70	lb.	97%	52.09	lb.	97%	52.09	lb.
Qualified Phenoline 305	Fines	0.48	ft^3	50.60	lb.	0.48	ft^3	50.60	lb.	97%	49.08	lb.	97%	49.08	lb.
Outside ZOI															
Unjacketed Temp-Mat	Fines	0.11	ft^3	1.33	lb.	0.38	ft^3	4.43	lb.	100%	1.33	lb.	100%	4.43	lb.
Unjacketed Cerablanket	Fines	0.00	ft^3	0.00	lb.	0.07	ft^3	0.55	lb.	100%	0.00	lb.	100%	0.55	lb.
Uncovered Fire Stop Kaowool	Fines	0.38	ft^3	2.28	lb.	0.38	ft^3	2.28	lb.	100%	2.28	lb.	100%	2.28	lb.
Unqualified IOZ	Fines	2.00	ft^3	446.00	lb.	2.00	ft^3	446.00	lb.	100%	446.00	lb.	100%	446.00	lb.
Unqualified Alkyd	9-mil chips	38.85	ft^3	4079.25	lb.	38.85	ft^3	4079.25	lb.	6.7%	273.31	lb.	6.7%	273.31	lb.
Unqualified High Heat Aluminum	2-mil chips	0.08	ft^3	8.00	lb.	0.08	ft^3	8.00	lb.	78%	6.24	lb.	78%	6.24	lb.

Table 4 - Transported Debris for Crossover Leg Break at Steam Generator 2 Nozzle

Inside ZOI		Crossover Leg Break at SG 2 Nozzle								Transported Debris					
Debris Type	Debris Size	Unit 1 Debris Quantity				Unit 2 Debris Quantity				Unit 1			Unit 2		
Stainless Steel RMI	Small Pieces (<4")	20,800	ft^2	-		20,800	ft^2	-		2%	416	ft^2	2%	416	ft^2
	Large Pieces (>4")	6,950	ft^2	-		6,950	ft^2	-		0%	0	ft^2	0%	0	ft^2
3M Foil Tape	Small Pieces (<4")	370	ft^2	-		370	ft^2	-		2%	7.40	ft^2	2%	7.40	ft^2
Temp-Mat	Fines	0.00	ft^3	0.00	lb.	0.00	ft^3	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Cal-Sil	Fines	0.94	ft^3	13.64	lb.	0.98	ft^3	14.27	lb.	97%	13.24	lb.	97%	13.84	lb.
Kaowool Blanket	Fines	0.02	ft^3	0.12	lb.	0.02	ft^3	0.12	lb.	97%	0.12	lb.	97%	0.12	lb.
Kaowool M Board	Fines	0.46	ft^3	7.82	lb.	0.46	ft^3	7.82	lb.	97%	7.59	lb.	97%	7.59	lb.
Marinite M Board	Fines	0.74	ft^3	34.04	lb.	0.74	ft^3	34.04	lb.	97%	33.02	lb.	97%	33.02	lb.
Mineral Wool in Pipe Fittings	Fines	1.91	ft^3	15.28	lb.	1.91	ft^3	15.28	lb.	97%	14.82	lb.	97%	14.82	lb.
Vapor Barrier Material	1/8" to 1/2" pieces	4.80	ft^2	-		4.48	ft^2	-		100%	4.80	ft^2	100%	4.48	ft^2
RTV Foam	1/8" to 1/2" pieces	2.36	ft^3	44.13	lb.	2.36	ft^3	44.13	lb.	100%	44.13	lb.	100%	44.13	lb.
Light Bulbs	1/8" to 1/2" pieces	133.00	ft^2	-		133.00	ft^2	-		0%	0.00	ft^2	0%	0.00	ft^2
Reflective Tape (Outside Crane Wall)	1/8" to 1/2" pieces	7.29	ft^2	-		7.29	ft^2	-		12%	0.87	ft^2	12%	0.87	ft^2
Conduit Tape (Outside Crane Wall)	1/8" to 1/2" pieces	2.27	ft^2	-		2.27	ft^2	-		13%	0.30	ft^2	13%	0.30	ft^2
Fiberglass (PZR Heater Cables)	Fines	0.18	ft^3	23.20	lb.	0.22	ft^3	28.64	lb.	97%	22.50	lb.	97%	27.78	lb.
Fiberglass (Flexicone Sleeving)	Fines	0.06	ft^3	7.58	lb.	0.07	ft^3	9.00	lb.	97%	7.35	lb.	97%	8.73	lb.
Silicone Rubber (Flexicone Sleeving)	1/8" to 1/2" pieces	33.05	ft^2	-		39.27	ft^2	-		1%	0.33	ft^2	1%	0.39	ft^2
Mica Tape (PZR Heater Cables)	Fines	0.29	ft^3	21.75	lb.	0.36	ft^3	26.85	lb.	97%	21.10	lb.	97%	26.04	lb.
3M Arc Prevention Tape	1/8" to 1/2" pieces	5.60	ft^2	-		5.60	ft^2	-		1%	0.06	ft^2	1%	0.06	ft^2
Cable Ties	1/8" to 1/2" pieces	0.19	ft^2	-		0.19	ft^2	-		32%	0.06	ft^2	32%	0.06	ft^2
Qualified Ameron 66	Fines	0.18	ft^3	17.80	lb.	0.18	ft^3	17.80	lb.	97%	17.27	lb.	97%	17.27	lb.
Qualified CZ-11	Fines	0.24	ft^3	53.70	lb.	0.24	ft^3	53.70	lb.	97%	52.09	lb.	97%	52.09	lb.
Qualified Phenoline 305	Fines	0.48	ft^3	50.60	lb.	0.48	ft^3	50.60	lb.	97%	49.08	lb.	97%	49.08	lb.
Outside ZOI															
Unjacketed Temp-Mat	Fines	0.11	ft^3	1.33	lb.	0.38	ft^3	4.43	lb.	100%	1.33	lb.	100%	4.43	lb.
Unjacketed Cerablanket	Fines	0.00	ft^3	0.00	lb.	0.07	ft^3	0.55	lb.	100%	0.00	lb.	100%	0.55	lb.
Uncovered Fire Stop Kaowool	Fines	0.38	ft^3	2.28	lb.	0.38	ft^3	2.28	lb.	100%	2.28	lb.	100%	2.28	lb.
Unqualified IOZ	Fines	2.00	ft^3	446.00	lb.	2.00	ft^3	446.00	lb.	100%	446.00	lb.	100%	446.00	lb.
Unqualified Alkyd	9-mil chips	38.85	ft^3	4079.25	lb.	38.85	ft^3	4079.25	lb.	7.7%	314.10	lb.	7.7%	314.10	lb.
Unqualified High Heat Aluminum	2-mil chips	0.08	ft^3	8.00	lb.	0.08	ft^3	8.00	lb.	78%	6.24	lb.	78%	6.24	lb.

Table 5 - Transported Debris for Pressurizer Relief Valve Inlet Breaks (Unit 1 Line 727; Unit 2 Line 728)

Inside ZOI		PZR RV Inlet Breaks (U1-Line 727;U2-Line 728)								Transported Debris					
Debris Type	Debris Size	Unit 1 Debris Quantity				Unit 2 Debris Quantity				Unit 1			Unit 2		
Stainless Steel RMI	Small Pieces (<4")	6,710	ft²	-		6,710	ft²	-		2%	134.2	ft²	2%	134.2	ft²
	Large Pieces (>4")	2,240	ft²	-		2,240	ft²	-		0%	0	ft²	0%	0	ft²
3M Foil Tape	Small Pieces (<4")	370	ft²	-		370	ft²	-		2%	7.40	ft²	2%	7.40	ft²
Temp-Mat	Fines	5.65	ft³	66.67	lb.	1.58	ft³	18.64	lb.	97%	64.67	lb.	97%	18.08	lb.
Cal-Sil	Fines	1.05	ft³	15.23	lb.	1.05	ft³	15.23	lb.	97%	14.77	lb.	97%	14.77	lb.
Kaowool Blanket	Fines	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Kaowool M Board	Fines	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Marinite M Board	Fines	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Mineral Wool in Pipe Fittings	Fines	0.61	ft³	4.91	lb.	0.61	ft³	4.91	lb.	97%	4.76	lb.	97%	4.76	lb.
Vapor Barrier Material	1/8" to 1/2" pieces	7.15	ft²	-		7.15	ft²	-		100%	7.15	ft²	100%	7.15	ft²
RTV Foam	1/8" to 1/2" pieces	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	100%	0.00	lb.	100%	0.00	lb.
Light Bulbs	1/8" to 1/2" pieces	133.00	ft²	-		133.00	ft²	-		0%	0.00	ft²	0%	0.00	ft²
Reflective Tape (Outside Crane Wall)	1/8" to 1/2" pieces	0.00	ft²	-		0.00	ft²	-		12%	0.00	ft²	12%	0.00	ft²
Conduit Tape (Outside Crane Wall)	1/8" to 1/2" pieces	0.00	ft²	-		0.00	ft²	-		13%	0.00	ft²	13%	0.00	ft²
Fiberglass (PZR Heater Cables)	Fines	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Fiberglass (Flexicone Sleeving)	Fines	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Silicone Rubber (Flexicone Sleeving)	1/8" to 1/2" pieces	0.00	ft²	-		0.00	ft²	-		1%	0.00	ft²	1%	0.00	ft²
Mica Tape (PZR Heater Cables)	Fines	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
3M Arc Prevention Tape	1/8" to 1/2" pieces	0.00	ft²	-		0.00	ft²	-		1%	0.00	ft²	1%	0.00	ft²
Cable Ties	1/8" to 1/2" pieces	0.00	ft²	-		0.00	ft²	-		32%	0.00	ft²	32%	0.00	ft²
Qualified Ameron 66	Fines	0.04	ft³	3.90	lb.	0.04	ft³	3.90	lb.	97%	3.78	lb.	97%	3.78	lb.
Qualified CZ-11	Fines	0.03	ft³	7.40	lb.	0.03	ft³	7.40	lb.	97%	7.18	lb.	97%	7.18	lb.
Qualified Phenoline 305	Fines	0.07	ft³	7.00	lb.	0.07	ft³	7.00	lb.	97%	6.79	lb.	97%	6.79	lb.
Outside ZOI															
Unjacketed Temp-Mat	Fines	0.11	ft³	1.33	lb.	0.38	ft³	4.43	lb.	100%	1.33	lb.	100%	4.43	lb.
Unjacketed Cerablanket	Fines	0.00	ft³	0.00	lb.	0.07	ft³	0.55	lb.	100%	0.00	lb.	100%	0.55	lb.
Uncovered Fire Stop Kaowool	Fines	0.38	ft³	2.28	lb.	0.38	ft³	2.28	lb.	100%	2.28	lb.	100%	2.28	lb.
Unqualified IOZ	Fines	2.00	ft³	446.00	lb.	2.00	ft³	446.00	lb.	100%	446.00	lb.	100%	446.00	lb.
Unqualified Alkyd	9-mil chips	38.85	ft³	4079.25	lb.	38.85	ft³	4079.25	lb.	7.7%	314.10	lb.	7.7%	314.10	lb.
Unqualified High Heat Aluminum	2-mil chips	0.12	ft³	12.23	lb.	0.12	ft³	12.23	lb.	78%	9.54	lb.	78%	9.54	lb.

Table 6 - Transported Debris for Pressurizer Surge Line Break Near Base of Pressurizer

Inside ZOI		PZR Surge Line Break near PZR Base								Transported Debris					
Debris Type	Debris Size	Unit 1 Debris Quantity				Unit 2 Debris Quantity				Unit 1			Unit 2		
Stainless Steel RMI	Small Pieces (<4")	15,300	ft²	-		15,300	ft²	-		2%	306	ft²	2%	306	ft²
	Large Pieces (>4")	5,100	ft²	-		5,100	ft²	-		0%	0	ft²	0%	0	ft²
3M Foil Tape	Small Pieces (<4")	370	ft²	-		370	ft²	-		2%	7.40	ft²	2%	7.40	ft²
Temp-Mat	Fines	1.32	ft³	15.58	lb.	1.32	ft³	15.58	lb.	97%	15.11	lb.	97%	15.11	lb.
Cal-Sil	Fines	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Kaowool Blanket	Fines	0.02	ft³	0.12	lb.	0.02	ft³	0.12	lb.	97%	0.12	lb.	97%	0.12	lb.
Kaowool M Board	Fines	0.19	ft³	3.23	lb.	0.19	ft³	3.23	lb.	97%	3.13	lb.	97%	3.13	lb.
Marinite M Board	Fines	0.74	ft³	34.04	lb.	0.74	ft³	34.04	lb.	97%	33.02	lb.	97%	33.02	lb.
Mineral Wool in Pipe Fittings	Fines	0.00	ft³	0.00	lb.	0.00	ft³	0.00	lb.	97%	0.00	lb.	97%	0.00	lb.
Vapor Barrier Material	1/8" to 1/2" pieces	0.00	ft²	-		0.00	ft²	-		100%	0.00	ft²	100%	0.00	ft²
RTV Foam	1/8" to 1/2" pieces	1.01	ft³	18.89	lb.	1.01	ft³	18.89	lb.	100%	18.89	lb.	100%	18.89	lb.
Light Bulbs	1/8" to 1/2" pieces	133.00	ft²	-		133.00	ft²	-		0%	0.00	ft²	0%	0.00	ft²
Reflective Tape (Outside Crane Wall)	1/8" to 1/2" pieces	3.50	ft²	-		3.50	ft²	-		12%	0.42	ft²	12%	0.42	ft²
Conduit Tape (Outside Crane Wall)	1/8" to 1/2" pieces	0.00	ft²	-		0.00	ft²	-		13%	0.00	ft²	13%	0.00	ft²
Fiberglass (PZR Heater Cables)	Fines	0.12	ft³	16.38	lb.	0.12	ft³	16.38	lb.	97%	15.89	lb.	97%	15.89	lb.
Fiberglass (Flexicone Sleeving)	Fines	0.12	ft³	15.15	lb.	0.14	ft³	18.00	lb.	97%	14.70	lb.	97%	17.46	lb.
Silicone Rubber (Flexicone Sleeving)	1/8" to 1/2" pieces	66.10	ft²	-		78.50	ft²	-		1%	0.66	ft²	1%	0.79	ft²
Mica Tape (PZR Heater Cables)	Fines	0.20	ft³	15.34	lb.	0.20	ft³	15.34	lb.	97%	14.88	lb.	97%	14.88	lb.
3M Arc Prevention Tape	1/8" to 1/2" pieces	5.60	ft²	-		5.60	ft²	-		1%	0.06	ft²	1%	0.06	ft²
Cable Ties	1/8" to 1/2" pieces	0.19	ft²	-		0.19	ft²	-		32%	0.06	ft²	32%	0.06	ft²
Qualified Ameron 66	Fines	0.04	ft³	3.90	lb.	0.04	ft³	3.90	lb.	97%	3.78	lb.	97%	3.78	lb.
Qualified CZ-11	Fines	0.03	ft³	7.40	lb.	0.03	ft³	7.40	lb.	97%	7.18	lb.	97%	7.18	lb.
Qualified Phenoline 305	Fines	0.07	ft³	7.00	lb.	0.07	ft³	7.00	lb.	97%	6.79	lb.	97%	6.79	lb.
Outside ZOI															
Unjacketed Temp-Mat	Fines	0.11	ft³	1.33	lb.	0.38	ft³	4.43	lb.	100%	1.33	lb.	100%	4.43	lb.
Unjacketed Cerablanket	Fines	0.00	ft³	0.00	lb.	0.07	ft³	0.55	lb.	100%	0.00	lb.	100%	0.55	lb.
Uncovered Fire Stop Kaowool	Fines	0.38	ft³	2.28	lb.	0.38	ft³	2.28	lb.	100%	2.28	lb.	100%	2.28	lb.
Unqualified IOZ	Fines	2.00	ft³	446.00	lb.	2.00	ft³	446.00	lb.	100%	446.00	lb.	100%	446.00	lb.
Unqualified Alkyd	9-mil chips	38.85	ft³	4079.25	lb.	38.85	ft³	4079.25	lb.	7.7%	314.10	lb.	7.7%	314.10	lb.
Unqualified High Heat Aluminum	2-mil chips	0.08	ft³	8.00	lb.	0.08	ft³	8.00	lb.	78%	6.24	lb.	78%	6.24	lb.

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.

- *Provide a schematic diagram of the emergency core cooling system (ECCS) and containment spray systems (CSS).*
- *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.*
- *Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions.*
- *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.*
- *Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen.*
- *Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial "thin bed" formation.*
- *Provide the basis for the strainer design maximum head loss.*
- *Describe significant margins and conservatisms used in the head loss and vortexing calculations.*
- *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation.*
- *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis.*
- *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.*
- *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.*
- *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.*
- *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.*

PG&E Response:

Strainer Head Loss, Fiber Bypass, and Fuel Bottom Nozzle Head Loss Testing

Provided below are: (1) an introduction to the testing program, (2) an overview of the test methodologies (strainer head loss testing, fiber bypass testing, and fuel bottom nozzle testing), (3) a detailed discussion of testing including results, and (4) a summary/conclusion.

Introduction to Test Program

Sump strainer head losses were determined though a combination of testing and analysis. Screen head losses were determined using a range of tests since no analytical methods are available. The testing performed was designed to assure that a conservative design basis head loss would be determined for DCPP. The head losses associated with the portion of the strainers downstream of the perforated plate screens (the strainer plenums and RHR piping entrance) were established using analytical methods.

The sector and module head loss tests were designed to simulate plant debris loads and strainer approach velocities to validate the final design. The testing performed included use of debris loadings representative of the design basis debris loads and included fiber, particulate, coating chips, and chemical precipitate debris. This testing program provides the basis for all strainer head losses and covers both clean-screen and debris-laden conditions.

In addition to strainer head loss testing, DCPP has performed fiber bypass testing to determine the quantity of fibrous debris which could potentially bypass the strainer and be capable of forming a debris bed on the fuel bottom nozzle. Fiber bypass was quantified by placing two fine filters downstream of the test sector to capture any bypassed fibrous debris. Using the actual bypassed fibrous debris, DCPP subsequently performed fuel bottom nozzle head loss testing.

DCPP has taken a number of actions to assure acceptable strainer performance. The actions have included consideration of screen sizing, a number of debris removal modifications, the installation of debris interceptors, strainer head loss testing, fiber bypass testing, fuel bottom nozzle head loss testing and vortex testing. These actions have demonstrated acceptable post accident head losses across the DCPP strainers and fuel bottom nozzles.

Strainer head loss, fiber bypass, fuel bottom nozzle head loss and strainer back flush testing was performed at the Continuum Dynamics, Inc (CDI) facilities in Ewing, New Jersey. Each safety-related test had a test plan and a test procedure that was prepared and performed under the CDI quality program. Reduced flow and vortex testing was also performed at CDI. Air ingestion testing of the flow straightening vanes in the plenum was performed at the PG&E ATS testing facilities in San Ramon, California. This testing was performed under the ATS quality program using ATS test procedures.

Strainer Head Loss Test Methodology Overview

DCPP head loss testing was performed using either a test sector or a test module. A test sector is a test article that represents a single strainer gap, while a test module represents a group of sectors, and more closely resembles a portion of a complete plant strainer.

The DCPP strainer consists of front sectors (with a plenum behind them) and rear sectors (with the plenum below them). Using the same debris loading per unit of strainer surface area and the same perforated plate approach velocity, DCPP has performed head loss tests using a front sector test article, a rear sector test article and a rear module test article. The rear sector test article showed similar, but lower head loss than the front sector test article while the module test article showed a very small head loss relative to either sector test article. Two factors can explain the low head loss of the module test article relative to the sector test articles: (1) the mixing for the sector tests was more effective than for the module test, and (2) because of the extended configuration and greater number of gaps in the module test article vice the sector test articles, there is a greater likelihood of uneven debris bed formation which will lead to a greater number of open holes and lower head loss. DCPP established that given the same debris load and flow conditions the front sector test article provides the most conservative (greatest) head loss. See Figures 1 and 2 for the sector head loss and module head loss test setups, respectively. Therefore, DCPP performed all design basis tests using the front sector test article.

Near field effects were not used as a basis to reduce any debris source. All debris shown to arrive at the strainer in the debris transport calculation is included in the scaled test debris loads. To minimize the possibility of settling in the test tank, debris was homogeneously mixed and maintained in suspension in the test pool using a combination of return flow from the pump and mechanical agitators. The sector head loss tests applied six mechanical agitators placed strategically around the outside of the strainer gap. This placement ensured that the debris remained in suspension, and did not adversely impact the formation of the filter bed in the gap. The mechanical agitators also ensure that the fibrous debris remains in suspension as fines and does not agglomerate. To aid in mixing all test debris was wetted prior to introduction into the test pool.

In many cases, actual plant materials were used as debris during testing. In other cases, a valid test surrogate with very similar characteristics (i.e. density, characteristic size, etc.) was used. The following table shows the plant material and the test surrogate:

Plant Material	Test Surrogate
Temp-Mat	Nukon[1]
Kaowool	Kaowool
Cerablanket	Nukon[1]
Marinite	Marinite
Mineral Wool	Mineral Wool
Pressurizer Heater Cable Fiberglass	Nukon[1]
Flexicone Sleeving Fiberglass	Nukon[1]
Mica Tape	PWR Dirt Mix (82.4%) and Fiberglass Tape (17.6%)
Cal-Sil	Cal-Sil
Particulate Coating Debris (in ZOI)	Sil-Co-Sil Sand
Coating Chip Debris	Coatings Chips (9-mil or 2-mil thickness, similar density)
Latent Dirt/Dust	PWR Dirt Mix
Latent Fiber	Nukon[1]

[1]Individual fibers of Nukon have a similar characteristic size to those of Temp-Mat, Cerablanket, and other fibrous debris, even though as-fabricated product densities vary.

Several fibrous test surrogate materials (Nukon and Mineral Wool) are in the form of fines and small clumps and require minimal preparation. These test surrogates are mixed with water from the test tank and kneaded until all debris is clearly soaked. Additional test tank water is then added and the material is mixed using a paint mixer thereby producing a slurry of individual fiber fines. Kaowool, which is in the form of a bat or blanket, is shredded with a leaf shredder prior to being kneaded and mixed in the same manner. Marinite, Cal-Sil, PWR dirt mix, and Sil-Co-Sil sand are in a particulate form and are mixed with test tank water to form a slurry prior to introduction into the test tank.

For miscellaneous debris sources (e.g. lamicoids, tags, etc.) that fail as small pieces and would block portions of strainer perforated plate, the total transported surface area (i.e. sacrificial screen area) was subtracted from the plant strainer surface area during scaling of debris loads. Chemical precipitate debris is calculated in Calculation M-1093 using the methodology contained in WCAP-16530-NP. For DCPP, the chemical precipitates which form in the post accident recirculation pool are sodium aluminum silicate and aluminum oxyhydroxide. The quantity of the chemical precipitate debris was pre-mixed in tanks and prepared in accordance with the recommendation in WCAP-16530-NP, with revised turbid volume acceptance criteria (based on DCPP test observations). Aluminum oxyhydroxide was used in lieu of sodium aluminum silicate during Tests 12-S-PSG, 14-S-PSG, and 15-S-PSG (see detailed discussion of these head loss tests) as is allowed in WCAP-16530-NP.

One head loss test (3-S-ECE using the front sector) was performed to establish the most conservative order of debris introduction (debris then chemical precipitates or vice versa). It was established that introducing debris before chemical precipitates provides the most conservative head loss. This order of test debris introduction is indicative of the order in which actual post accident debris and chemical precipitates would be expected to arrive at the strainer. Chemical precipitates are not postulated to form until late in the accident chronology when recirculation pool temperatures are relatively cool.

For all sector head loss tests, the tests were continued until steady state head loss was reached. For all tests up to Test 11-S-PSG, steady-state head loss was reached when there was less than a 1 percent or 0.1-inch increase in measured head loss for at least 30 minutes or 5 turnover times, whichever was longer. The test termination criteria were revised for Test 11-S-PSG and all subsequent tests so that head loss tests were continued for a minimum of 24 hours after addition of the last chemical precipitates to approximate the number of turnovers for the 30-day ECCS mission time. See discussion on Tests 9-S-PSG and 11-S-PSG for details.

Strainer Head Loss Acceptance Criteria and Total Head Loss Calculations

RHR pump NPSH is determined within Calculation N-100. In order to have adequate NPSH margin for the RHR pumps, this calculation establishes a maximum acceptable strainer head loss of 33 inches at 100°F (this does not include the plenum or RHR entrance head losses, only the strainer). Test tank temperatures were maintained between 85°F and 98°F using either a heating or cooling coil.

The design basis test results showed that boreholes were present. The presence of boreholes would preclude any scaling of the test results with either water viscosity or debris bed thickness. The velocity scaling was accomplished primarily through use of scaled flow rates in the design basis sector test with some minor additional scaling required to account for flow measurement uncertainty.

Plenum head losses are due to the hydraulic losses associated with flow through the front and rear plenums and out the plenums to the RHR suction inlet in both the east and the west directions. The plenum head loss calculation includes the impact of various constrictions such as the floating sleeve attachments for the front plenum sections and the narrowing in the rear plenums as well as the effect of the flow straightener vanes installed in the east and west front plenum elbows and the vortex suppressors installed in the outlet pipe of the front strainer between the elbows and the RHR suction. These calculations utilized typical industry head loss calculation methods such as, "Flow of Fluids Through Valves, Fittings, and Pipe" (Crane Technical Paper No. 410), and the "Handbook of Hydraulic Resistance" (i.e., Idelchik), to determine the hydraulic losses in the plenum. The maximum predicted head loss for the plenums is 0.681 ft.

In addition to the strainer and plenum head losses, there is a head loss at the entrance from the plenum to the RHR suction pipe. This entrance has a 1/4-inch chamfer with rounded off edges. The entrance head loss is determined within Calculation N-100 using typical industry methodology and a conservative entrance loss coefficient of 0.4. The maximum predicted entrance head loss is 1.02 ft.

After conservatively accounting for the strainer, plenum and entrance head losses, DCPP has at least 1 foot of NPSH margin.

Fiber Bypass Test Methodology Overview

During actual post accident conditions, debris in the recirculation pool would arrive first at the front sectors, then at the rear sectors. It is therefore reasonable to assume that a debris bed would form more quickly on the front sectors than the rear, preventing significant fiber bypass in the front sectors. The rear sector demonstrated a lower head loss than the front sector (meaning it had more clean screen area for fiber bypass), and could be situated in a more compact test tank than the front sector, (because the footprint of a rear sector is much smaller than for a front sector), making it easier to achieve a homogenous fiber debris mix within the test tank. Using the above conclusions, DCPP established that the rear sector is the most conservative test article for use during fiber bypass tests.

Fiber bypass tests included fibrous debris only. Chemical precipitate and particulate debris were not used, since these types of debris would block perforated plate holes, potentially reducing fiber bypass.

A total of four fiber bypass tests were conducted using the rear sector test article. Two filters in series were placed in the outlet pipe to collect all of the bypassed fiber and prevent it from being recirculated. See Figure 3 for the fiber bypass test setup.

Fibrous debris for bypass testing was prepared in a similar manner to fibrous debris used during strainer head loss testing, and was agitated similarly to maintain the fiber in suspension.

Fuel Bottom Nozzle Head Loss Test Methodology Overview

The test article for the fuel bottom nozzle head loss tests consisted of a simulated core support plate, a bottom nozzle, a P-grid, an intermediate support grid, simulated fuel rods and simulated control rods. See Figures 4 and 5 for the fuel bottom nozzle head loss test setup.

Fuel bottom nozzle head loss tests were conducted using the actual fibrous debris which bypassed the test sector during the fiber bypass tests with maximum particulate debris (it was conservatively assumed that 100 percent of the particulate debris which arrives at the strainer also arrives at the fuel bottom nozzle). Unqualified inorganic zinc and unqualified high heat aluminum coatings were conservatively assumed to fail as particulate debris when conducting the fuel bottom nozzle head loss tests, and were conservatively assumed to fail as chips when conducting strainer head loss tests. Fuel bottom nozzle head loss tests conservatively included all chemical precipitate debris (some of these precipitates would be filtered out of solution by the debris bed on the strainer plates).

Detailed Strainer Head Loss Testing Discussion Including Results

DCPP conducted a total of fourteen sector head loss tests. The sector head loss tests with a summary of their respective debris loads are shown below, followed by a detailed discussion of each test.

- 1-FSHL[1]
- 2-RSHL[2]
- 3-S-ECE[3]
- 4-S-RPT[4]
- 5-S-RPT
- 6-S-RPT
- 7-S-RPT
- 8-S-PSG[5]
- 9-S-PSG
- 10-S-PSG
- 11-S-PSG[6]
- 12-S-PSG
- 14-S-PSG[6]
- 15-S-PSG[6]

Notes:

1. Front sector head loss test.
2. Rear sector head loss test.
3. S denotes Sector; ECE denotes Early Chemical Effects. The front Sector was used for Test 3-S-ECE and all subsequent sector head loss tests.
4. RPT denotes Repeatability.
5. PSG denotes Post Steam Generator (debris).
6. Design verification test.
7. A test designation of "13-S-PSG" was not used.

Sector Test Unscaled Plant Debris Loads

Test	Fibrous Debris[1] (lbs)	Particulate Debris[2] (lbs)	9-mil Coating Chips (lbs)	2-mil Coating Chips[3] (lbs)	Calcium Silicate (lbs)	Sacrificial Screen Area (ft^2)	Aluminum Oxyhydroxide (lbs)	Sodium Aluminum Silicate (lbs)	Test Scaling Factor[4]
1-FSHL	68.33	619.19	708.75	0.00	0.00	117.50	24.69	70.33	0.006764
2-RSHL	68.33	619.19	708.75	0.00	0.00	117.50	24.69	70.33	0.007024
3-S-ECE	68.33	619.19	708.75	0.00	0.00	117.50	24.69	70.33	0.006764
4-S-RPT	68.33	619.19	708.75	0.00	0.00	117.50	24.69	70.33	0.006764
5-S-RPT	68.33	619.19	708.75	0.00	0.00	117.50	24.69	70.33	0.006764
6-S-RPT	68.33	619.19	708.75	0.00	0.00	117.50	24.69	70.33	0.006764
7-S-RPT	68.33	619.19	708.75	0.00	0.00	117.50	24.69	70.33	0.006764
8-S-PSG	111.20	718.93	519.75	0.00	17.30	117.00	128.84	95.17	0.006763
9-S-PSG	109.93	717.69	708.75	0.00	17.30	140.31	140.76	120.16	0.006814
10-S-PSG	109.93	717.69	708.75	0.00	17.30	140.31	140.76	120.16	0.006814
11-S-PSG	83.61	704.41	511.36	0.00	17.30	139.91	144.55	97.58	0.006814
12-S-PSG	48.03	669.71	330.75	6.24	58.51	201.05	153.12	96.06[5]	0.006952
14-S-PSG	120.79	536.00	314.69	9.54	14.77	131.58	164.28	87.03[5]	0.006795
15-S-PSG	42.47	669.71	275.35	6.24	58.51	201.05	153.69	92.75[5]	0.006952

[1]Fibrous debris includes Temp-Mat, Cerablanket, Kaowool, Mineral Wool, Fiberglass tape, and latent fiber.
[2]Particulate debris includes marinite, particulate coatings debris, mica and latent dirt/dust.
[3]2-mil coating chips were not considered as a debris source until Test 12-S-PSG.
[4]For all debris types other than chemical precipitates, the test quantity is the plant quantity multiplied by the scaling factor. Debris scaling factors are determined using the following equation:

$$Scaling\ Factor = \frac{Test\ Article\ Perforated\ Plate\ Area\ (20.85\ ft^2;\ 21.65\ ft^2\ for\ 2-RSHL)}{Plant\ Strainer\ Perforated\ Plate\ Area\ (3200\ ft^2) - Sacrificial\ Screen\ Area\ (Break\ Specific)}$$

and,

$$Test\ Debris = (Plant\ Debris)(Scaling\ Factor)$$

For chemical precipitates, scaling is accomplished using the following equation:

$$Test\ precipitates = (Plant\ precipitates)(Scaling\ Factor)(Storage\ Tank\ Concentration)(Weight\ per\ gallon\ of\ mixed\ solution)$$

where,

$$Storage\ Tank\ Concentration = \frac{10\ gal}{0.92\ lbs}\ \text{and}\ Weight\ per\ gallon\ of\ mixed\ solution = \frac{8.5\ lbs}{gal}\ for\ ALOOH;\ \frac{8.44\ lbs}{gal}\ for\ NAS$$

[5]As is allowed in WCAP-16530-NP, aluminum oxyhydroxide was used in lieu of sodium aluminum silicate for these tests.

Sector Test Scaled Debris Loads

Test Debris Type	Test Number[1] and Scaled Test Debris Quantities (lbm)							
	Test 1 and 3-7	Test 2	Test 8	Tests 9 and 10	Test 11	Test 12	Test 14	Test 15
Rock Wool	0.08	0.09	0.11	0.11	0.11	0.10	0.03	0.10
Nukon	0.32	0.33	0.51	0.51	0.35	0.14	0.77	0.10
Kaowool	0.04	0.04	0.07	0.07	0.07	0.09	0.02	0.09
Fiberglass Tape	0.02	0.02	0.06	0.06	0.04	0.00	0.00	0.00
PWR Dirt Mix	0.59	0.61	0.77	0.76	0.67	0.50	0.49	0.50
Marinite	0.22	0.23	0.22	0.22	0.22	0.23	0.00	0.23
Sil-Co-Sil	3.38	3.51	3.87	3.90	3.90	3.98	3.23	3.98
Cal-Sil	0.00	0.00	0.12	0.12	0.12	0.41	0.10	0.41
Paint Chips[2]	4.79	4.98	3.52	4.83	3.48	2.34	2.20	1.96
NAS[3]	43.64	45.32	59.05	75.11	61.00	61.26	54.25	59.15
ALOOH[3]	15.43	16.02	80.50	88.62	91.00	98.35	103.13	98.72

[1]Only the numerical designator for each test is included as the test number.
[2]Both the 9-mil and 2-mil paint chips are included in this quantity.
[3]These values are weights of precipitate solutions prepared in accordance with WCAP-16530-NP.

Head loss Tests 1-FSHL, 2-RSHL, 3-S-ECE, 4-S-RPT, 5-S-RPT, 6-S-RPT, and 7-S-RPT were conducted using the debris load from a pressurizer surge line break near the base of the pressurizer.

1-FSHL and 2-RSHL

Test 1-FSHL was conducted using a front sector test article. Test 2-RSHL was conducted with identical conditions and plant debris load as 1-FSHL, but using a rear sector test article. Both 1-FSHL and 2-RSHL showed minimal head loss (approximately 2.5 inches for 1-FSHL, and 2.3 inches for 2-RSHL). Post-test inspection of the test articles showed that most debris had accumulated near the plenum with very little debris noted at the end of the strainer far from the plenum. Both tests showed debris filling in the gap near the plenum. Approximately 40 percent to 50 percent of the perforated plate area was covered by a debris bed.

Based on the higher head loss observed during Test 1-FSHL and the more uniform debris distribution (the rear sector article showed a greater accumulation of debris near the plenum), the front sector test article was established as being the most conservative (higher head loss) sector test article. All subsequent sector head loss tests were performed using the front sector test article.

3-S-ECE, 4-S-RPT, 5-S-RPT, 6-S-RPT, and 7-S-RPT

Head loss Test 3-S-ECE was an exploratory test to establish whether chemical precipitates alone could create a head loss. During Tests 1-FSHL and 2-RSHL, fibrous and particulate debris were introduced before chemical precipitates. Test 3-S-ECE used the same debris and chemical precipitate quantities as Tests 1-FSHL and 2-RSHL, but chemical precipitates were introduced prior to fibrous and particulate debris. During Test 3-S-ECE, there was no measured head loss until fibrous and particulate debris were introduced in the test tank, meaning chemical precipitates alone do not produce a head loss. An important conclusion can be drawn from this observation. Chemical precipitates need an established filtering debris bed in order to contribute to head loss, and otherwise continuously recirculate through clean screen area. Subsequent tests would be performed by introducing chemical precipitates after fibrous and particulate debris so that a filtering debris bed would already be established. This order of debris introduction also mimics what would actually be expected post accident, since chemicals do not precipitate out of solution until recirculation pool temperatures have cooled.

Tests 4-S-RPT, 5-S-RPT, 6-S-RPT, and 7-S-RPT were intended to assess the repeatability of test results. Unlike Tests 1-FSHL and 2-RSHL, a measurable head loss was observed during Tests 3-S-ECE (after the addition of fibrous and particulate debris) and the four repeatability tests. The following table summarizes the maximum head loss during 3-S-ECE and the four repeatability tests.

Head Loss Test	Maximum Head Loss (in.)
3-S-ECE	22.5
4-S-RPT	46.5
5-S-RPT	59.5
6-S-RPT	26.5
7-S-RPT	33.0

Post-test inspection of the test articles for Tests 3-S-ECE and the four repeatability tests showed that there were significantly more perforated plate holes plugged than for Tests 1-FSHL and 2-RSHL. Unlike the first two tests, thinner layers of debris were observed to have plugged holes during Test 3-S-ECE and the four repeatability tests, and did so without the presence of fiber in the debris bed. These layers contained chemical precipitates only and did not require a fiber bed underneath to plug holes. Very little clean screen area was observed in Test 3-S-ECE and the four repeatability tests.

Test 3-S-ECE and the four repeatability tests used chemical precipitates which had aged longer than those used during Tests 1-FSHL and 2-RSHL. It was suspected that a morphological change had occurred in the chemical precipitates as they aged, giving them the ability to plug holes in the strainer perforated plates without the presence of a fiber bed.

Despite having higher head losses than Tests 1-FSHL and 2-RSHL, Tests 4-S-RPT, 5-S-RPT, 6-S-RPT, and 7-S-RPT were repeatable with respect to the location, thickness, and characteristics of the debris bed. The head loss values varied between the repeatability tests, but there was a clear correlation between the number of open holes observed during post-test inspection and the head loss.

Based on the higher head losses observed when using aged chemicals, additional analyses and tests were performed on the chemical precipitates. From the results of microscopic analysis, gravity head loss tests and the results of turbidity tests, it was concluded that the physical properties of aluminum oxyhydroxide change with time. These changes become so pronounced that they eventually affect the test results. Tests 1-FSHL and 2-RSHL were conducted with the turbid fraction of aluminum oxyhydroxide being between 80 percent and 90 percent. Test 3-S-ECE and the four repeatability tests were conducted with turbid fractions ranging between 42 percent and 58 percent. It took approximately 30 days for chemical precipitates to begin exhibiting this significantly higher settling rate. See Figure 6 for a plot of the aluminum oxyhydroxide turbid volumes vs. time. The points plotted on Figure 6 are the turbidity readings at the time of Tests 1-FSHL through 6-S-RPT. The aluminum oxyhydroxide was prepared on November 16, 2006.

An assumption in the WCAP-16530-NP methodology is that any chemical precipitates formed in the sump pool are transported to the sump screen and are either captured by the sump screen or settle out elsewhere in the recirculation path relatively shortly upon forming. Therefore, in accordance with the methodology of WCAP-16530-NP, un-aged (high turbid fraction) chemical precipitates should be used for head loss testing. Westinghouse has confirmed that un-aged chemical precipitates more closely model actual plant accident conditions. For all tests conducted after Test 7-S-RPT, the allowable turbid fraction for aluminum oxyhydroxide and sodium aluminum silicate was revised to 90 percent minimum (from 40 percent).

Because of the changing physical properties of the aluminum oxyhydroxide, it is believed that the head loss results for Test 3-S-ECE and the four repeatability tests are questionable.

8-S-PSG, 9-S-PSG, and 10-S-PSG

Test 8-S-PSG was conducted using the debris from a Loop 2 crossover leg break at the SG nozzle. Tests 9-S-PSG and 10-S-PSG were conducted using revised debris loads for the Loop 2 crossover leg break at the SG nozzle; most significantly, the unqualified coatings chip debris was increased to provide margin over the calculated quantities.

The inspections of the test tank after 8-S-PSG noted settling of some of the unqualified coatings chips, which potentially gave nonconservative head loss results for that test. Test tank agitation was altered for subsequent tests to ensure settling or hideout of unqualified coatings chips was kept to a minimum. With more unqualified coatings chips in suspension (due to change in agitation and chip debris load), Tests 9-S-PSG and 10-S-PSG demonstrated higher head losses than Test 8-S-PSG (40.1 inches and 42.4 inches respectively, vice 25.2 inches for Test 8-S-PSG; see Figure 7 for plots of head loss vs. time for Tests 8-S-PSG, 9-S-PSG, and 10-S-PSG). Post-test inspections of the test article confirmed that coatings chips block perforated plate holes, and can filter out chemical precipitates, thereby explaining their effect on head loss. Test 8-S-PSG showed approximately 10 percent clean screen area while Tests 9-S-PSG and 10-S-PSG showed approximately 1 percent clean screen area.

After Test 9-S-PSG had reached the test termination criteria with a head loss of 40.1 inches, the flow rate was reduced to evaluate the affect on head loss. Head loss dropped when the flow rate was reduced, but relatively quickly increased to a maximum of 46.3 inches, and again reached the termination criteria. The test flow rate was reduced even further and head loss dropped again when the flow rate was reduced. Again however, the head loss quickly increased to a maximum of 42.5 inches and reached the termination criteria a third time. The higher head loss measured at a lower flow rate was possibly due to shifting of the debris bed, or due to not reaching the final termination at the first flow rate. This observation led to the revised test termination criteria used for Tests 11-S-PSG through 15-S-PSG.

See Figures 8 through 12 for photos of the test sector for Tests 8-S-PSG, 9-S-PSG, and 10-S-PSG. Note the extensive coverage of the front areas of the test sector in Tests 9-S-PSG and 10-S-PSG by unqualified coatings chips.

11-S-PSG

Although repeatable, the head loss observed during Tests 9-S-PSG and 10-S-PSG would not provide adequate head loss margin when considered in the NPSH calculation for the RHR pumps, which allows a maximum head loss of 33 inches for the strainer.

Because of their effect on clean screen area observed during Tests 9-S-PSG and 10-S-PSG, the unqualified coatings chip debris for Test 11-S-PSG was decreased to current calculated values with minimal margin (Tests 9-S-PSG and 10-S-PSG included considerable margin on current calculated values) and a reduced transport fraction was assumed. Removal of overconservatisms within the debris generation analysis reduced the fibrous debris from the Loop 2 crossover leg break at the SG nozzle.

The decrease in unqualified coatings chip debris provided the expected results of decreased head loss. Note in Figures 13 and 14 the less extensive perforated plate coverage by unqualified coatings chips when compared to Figures 9 through 12 of Tests 9-S-PSG and 10-S-PSG. The final head loss measured during Test 11-S-PSG was 31.5 inches, and post-test inspections showed approximately 2.5 percent clean screen area. See Figure 21 for a plot of the head loss vs. time for Test 11-S-PSG.

It was recognized before Test 11-S-PSG that the termination criteria of less than 1 percent increase in head loss in 30 minutes (or 5 turnover times) could be met even though the head loss was still increasing (see discussion on Test 9-S-PSG). For Test 11-S-PSG through 14-S-PSG the test termination criteria were revised so that head loss tests were continued for a minimum of 24 hours after addition of the last chemical precipitates to approximate the number of turnovers for the 30-day ECCS mission time.

From the testing, DCPP concluded that head loss values will continue to increase until you have either completely filtered all chemical precipitates out of solution, or the debris bed becomes saturated with chemicals and all flow is through clean screen area. Clean screen area will remain while the debris bed increases in thickness as it filters chemical precipitates out of solution. Head loss will stabilize once all flow is through low concentration paint chip bed areas (not able to filter chemicals) and/or clean screen area. Head loss values will continue to sawtooth as debris bed bore holes open and close.

12-S-PSG

Head loss Test 12-S-PSG was conducted using the debris load from a Loop 4 crossover leg break at the reactor coolant pump nozzle. This break produces substantial cal-sil debris. All of the previous testing used high fiber debris loads. This test used unqualified coating chips debris with considerable margin over the current calculated quantities, but used a further reduced transport fraction that was determined by testing of debris interceptors. The sodium aluminum silicate which was prepared for use during Tests 12-S-PSG, 14-S-PSG, and 15-S-PSG showed abnormal characteristics (extremely viscous/thick) and was not used during these tests. For Tests 12-S-PSG, 14-S-PSG, and 15-S-PSG aluminum oxyhydroxide was used in lieu of sodium aluminum silicate, as is allowed in WCAP-16530-NP.

The head loss curve for Test 12-S-PSG (see Figure 21) showed random and sizeable sawtoothing, believed to be due to opening and closing of bore holes and breakthroughs (large bore holes). The maximum measured head loss during Test 12-S-PSG was 36.3 inches, which does not meet the acceptance criteria of 33 inches.

As was discovered when comparing head loss Tests 9-S-PSG and 10-S-PSG to Test 11-S-PSG, unqualified coatings chips contribute heavily to blocking perforated plate holes thereby increasing head loss. Note in Figures 15 and 16 the extensive coverage of the front areas of the test sector with unqualified coatings chips. Test 15-S-PSG used the same debris load as Test 12-S-PSG, but the unqualified coatings debris was reduced to include minimal margin over current calculated quantities.

See Figures 15 and 16 for photos of the test sector for Test 12-S-PSG.

14-S-PSG

Subsequent to the performance of Test 11-S-PSG, revisions to the debris generation analyses identified a new more limiting break in terms of fibrous debris generation than the Loop 2 crossover leg break used for Tests 8-S-PSG through 11-S-PSG. Head loss Test 14-S-PSG was conducted using the debris load from a break in the inlet line to Pressurizer Safety Valve 8010C (Line 727). This break generates substantially more fiber than the Loop 2 crossover leg break at the SG nozzle. Because the unqualified coating margin was lost during Test 12-S-PSG, Test 14-S-PSG included minimal margin for unqualified coatings over the current calculated quantities. As discussed above, aluminum oxyhydroxide was used in lieu of sodium aluminum silicate.

The reduced quantity of unqualified coatings chips used during this test proved to have a substantial impact on head loss. The head loss for Test 14-S-PSG (see Figure 21 for the head loss curve) increased slowly, with a maximum head loss of 6.1 inches. Post-test inspections showed substantial clean screen area with much less screen area blocked by unqualified coatings chips. When compared with the other high fiber Tests (9-S-PSG through 11-S-PSG) the debris beds were reasonably similar, except for an absence of unqualified coatings chips on much of the sector. It appeared as though the additional fibrous debris (over that used in Tests 9-S-PSG through 11-S-PSG) only impacted the strainer by the formation of a larger mass of fiber bridging the gap area near the plenum.

See Figures 17 and 18 for photos of the test sector for Test 14-S-PSG.

15-S-PSG

Due to the failure of Test 12-S-PSG (attributed predominately to the impact of unqualified coatings chips on reducing clean screen area), Test 15-S-PSG used the same debris load with reduced unqualified coatings chips debris. As was seen during Test 14-S-PSG, unqualified coatings chips can have a dramatic affect on head loss by reducing clean screen area. The debris bed seen during Test 15-S-PSG was similar to those seen during Tests 9-S-PSG through 14-S-PSG. As anticipated, the reduction in unqualified coatings chips from Test 12-S-PSG gave a reduction in head loss. The maximum head loss measured during Test 15-S-PSG was 25.8 inches. Test 15-S-PSG showed a slightly higher head loss before the addition of chemical precipitates than did Test 12-S-PSG. Post-test inspections of the sector showed that fiber bed and coatings chip bed areas were thinner and slightly more extensive, which might explain the higher head loss measured before the addition of the chemicals. See Figure 21 for the head loss curve for 15-S-PSG.

See Figures 19 and 20 for photos of the test sector for Test 15-S-PSG.

Fiber Bypass Testing Results

A total of four fiber bypass tests were conducted. The tests were labeled 1-BYP, 2-BYP, 3-BYP, and 4-BYP. The first three fiber bypass tests used the debris from a pressurizer surge line break near the base of the pressurizer. The forth fiber bypass test used the debris from a crossover leg break at the SG 1-2 nozzle, which has more fibrous debris than for the surge line break used in the first three bypass tests. Test 3-BYP used smaller increments of fibrous debris, which proved to increase fiber bypass. However Test 4-BYP, which used a larger fibrous debris load than Test 3-BYP, and the same number of fibrous debris increments, showed less fiber bypass.

If fibrous debris were introduced one fiber at a time, bypass would be infinite. If an overwhelming quantity of fibrous debris reaches a perforated plate at the same time, a filtering bed will be established quickly and will prevent significant fiber bypass. DCPP has confirmed this hypothesis through fiber bypass testing. The increased number of debris increments in Test 3-BYP increased the total fiber bypass from what was observed during the first two tests. However, the greater fibrous debris load used during Test 4-BYP established a filtering bed which limited total bypass to less than was observed during the third test. The final fiber additions during Tests 1-BYP, 2-BYP, and 3-BYP correspond to a total nominal bed thickness of 0.090 inch, and the final fiber addition during Test 4-BYP corresponds to a total nominal bed thickness of 0.140 inches. Each fiber addition corresponds to an extremely thin debris bed, conservatively providing a large amount of clean screen area for fiber bypass, particularly for the first few debris additions. The results of the fiber bypass testing are presented in the table below.

Test	Total Scaled Fibrous Debris (g)	Debris Increments	Total Fiber Bypass (g)	Total Fiber Bypass (%)
1-BYP	207.8	5	13.6	6.54%
2-BYP	207.8	5	10.5	5.05%
3-BYP	207.8	10	17.1	8.23%
4-BYP	326.8	10	11.2	3.43%

The fiber bypass testing performed by DCPP has established a bounding range of total fiber bypass. By using two different fibrous debris loads, the most conservative test article for fiber bypass and conservative debris introduction, DCPP has demonstrated an approximate upper and lower limitation on fiber bypass. Test 3-BYP provided the design basis maximum fiber bypass and this quantity was used for subsequent fuel bottom nozzle head loss testing.

Fuel Bottom Nozzle Head Loss Testing

Four fuel bottom nozzle head loss tests were initially conducted. These tests were labeled 1-BNT, 2-BNT, 3-BNT, and 4-BNT. The fiber debris load was the same for all four tests, and was obtained from fiber that bypassed the rear sector test article during the fiber bypass tests. The quantity of fibrous debris used during all bottom nozzle tests was scaled from the maximum fiber bypass observed during Test 3-BYP. The purpose of this series of tests was to determine head loss across the fuel and bottom nozzle, and to evaluate repeatability of results, sensitivity to sequence of debris arrival, and variations in flow resistance through the fuel assembly for hot leg or cold leg break flow rates. Flow rates used during the tests are scaled from the flow rate that would be expected following a hot leg break (41.1 gpm) and from a cold leg break (5 gpm) that matches the core boiloff rate. All flow rates and debris quantities were scaled to represent that expected for 1 fuel assembly out of a 193 fuel assembly core.

After submitting the supplemental response in February 2008, deficiencies were identified in the bottom nozzle design basis test of record, 4-BNT, namely, the debris load no longer enveloped the debris load from the limiting break for the strainer, and details of the test methodology were potentially nonconservative. Further evaluation of photos of the results of Tests 1-BNT and 2-BNT showed significant air bubbles had formed on and around the bottom nozzle. These air bubbles existed in the test tank at test initiation and subsequently migrated to the bottom nozzle and may have adversely affected the formation of the fiber bed. Tests 1-BNT through 4-BNT all applied two different flow rates during the course of each test. The debris bed was formed at 5 gpm, and then at the conclusion of each test the flow rate was increased to 41.1 gpm.

To correct these deficiencies, six additional fuel bottom nozzle tests were performed in May 2008. The scope of these tests included an evaluation of both the current (Alternate P-Grid) and future installation of the Westinghouse Standard P-Grid. The tests with the Alternate P-Grid were:

Break Types for Bottom Nozzle Tests

Test Number	Break	Break Type
1-BNT 2-BNT 3-BNT	Surge Line Break at the Base of the Pressurizer (Alternate Break #9 January 2007)	High fiber Alternate Break
4-BNT	Loop 2 Crossover Leg Break at the Steam Generator (S/G) Nozzle January 2007	High Fiber
5-BNT 6-BNT	Loop 2 Crossover Leg Break at the Steam Generator (S/G) Nozzle (14-S-PSG)	High Fiber
7-BNT 8-BNT 9-BNT	Loop 4 Crossover Leg Break at the RCP Nozzle (15-S-PSG)	High Cal-Sil
12-BNT	Loop 4 Crossover Leg Break at the RCP Nozzle (15-S-PSG)	High Cal-Sil

Test 12-BNT was added to reflect a correction to the fiber debris scaling factor, and determine the effect of a 0.34-pound increase in fiber loading. Test 12-BNT also determined flow with a totally blocked inlet nozzle.

The following table shows the unscaled debris quantities for each test:

Plant Debris (Unscaled)

Test	Scaling Factor	Fibrous Debris (lbs)[1]	Particulate Debris PWR Dirt Mix (lbs)[2]	Particulate Debris Silica Sand (lbs)[3]	Calcium Silicate (lbs)	Marinite (lbs)	Sodium Aluminum Silicate (lbs)	Aluminum Oxyhydroxide (lbs)
1 - 3	0.005181	5.37	86.85	499.85	-	32.81	70.33	24.69
4-BNT	0.005181	5.37	113.87	572.23	17.28	32.81	95.17	128.84
5 - 6	0.005181	5.37	93.74	572.44	13.84	33.02	93.14	188.89
7 – 9	0.005181	5.37	72.25	564.44	58.51	33.02	96.06	167.93
12-BNT	0.005181	5.71	72.25	564.44	58.51	33.02	96.06	167.93

[1]This fibrous debris quantity is the unscaled fiber bypass quantity from Test 3-BYP.
[2]Particulate debris includes mica and latent dirt/dust.
[3]Particulate debris includes particulate coatings debris.

During Tests 1-BNT, 2-BNT, and 4-BNT, fibrous debris was introduced prior to chemical precipitates and particulate debris. For Test 3-BNT, the order of debris introduction was altered to determine the effect on fuel bottom nozzle head loss. For Test 3-BNT, chemical precipitate debris were introduced prior to fibrous debris. The Test Plan for Tests 5-BNT through 12-BNT called for the fiber debris to be added right after the particulate debris, the head loss stabilized, and then chemicals added.

The bottom nozzle test termination criteria were that each test be continued until steady state head loss was reached. Steady state head loss is defined as an increase in head loss over a 30-minute period of less than or equal to one percent or 0.1 inch of water (whichever is greater). An average head loss was used to determine the test termination. The test criteria required termination if the "maximum test allowable head loss" of 120 inches of water (a test facility limitation) was reached.

The final measured head loss for each test is shown in the following table.

Bottom Nozzle Test Results

Test BNT	Flow Rate (Gpm)	Head Loss (inches H_2O)
1-BNT a	5	2.8
1-BNT b	41.1	5.4
2-BNT a	5	3.5
2-BNT b	41.1	14.9
3-BNT a	5	5.6
3-BNT b	41.1	7.9
4-BNT a	5	12.9
4-BNT b	41.1	70.8
5-BNT	41.1	16.6
6-BNT	41.1	11.3
7-BNT	41.1	22.6
8-BNT	41.1	24.5
9-BNT	5	11.3
12-BNT	41.1	20.4
Blocked nozzle-a	5	9.3
Blocked nozzle-b	36.9	118.9

1. For Tests 1-BNT through 4-BNT, the initial flow rate was 5 gpm during debris/chemicals addition. The flow rate was raised to 41.1 gpm at test conclusion.
2. For Tests 5-BNT through 9-BNT and 12-BNT, the flow rate was constant for entire test.
3. For Test 3-BNT, chemical precipitates were added first, followed by debris. All other tests, debris was added before chemical precipitates.
4. For Test 5-BNT through Test 12-BNT, blocked nozzle-a and blocked nozzle-b, the head loss values are preliminary uncorrected values.

As was demonstrated during sector head loss testing, chemical precipitates need an established filtering bed to contribute a head loss, making the order of debris introduction of little significance. Tests 5-BNT and 6-BNT showed good repeatability as did Tests 7-BNT, 8-BNT and 12-BNT. The blocked nozzle test showed the head loss from flow around the edges of the bottom nozzle. As the flow rate increased to 36.9 gpm, the head loss approached the limit of the test assembly (120 inches of water).

The head loss effects were evaluated by Westinghouse through a comparison between the measured head loss of the 4-BNT test data and available driving head for the various DCPP LOCA scenarios. The Westinghouse comparisons showed that sufficient driving head is available to match the head loss due to debris buildup; therefore, adequate flow will enter the core to match boil-off, and the core will remain covered. Because the core remains covered, no late heatup occurs. Fuel head loss is discussed in more detail in Section 3.n, Downstream Effects – Fuel and Vessel.

Summary/Conclusion

Through extensive testing DCPP has demonstrated acceptable post-accident performance of the RHR strainer and fuel bottom nozzle with debris laden fluid. DCPP has determined and verified through testing that there will be acceptable head loss and the existence of clean screen area for all breaks.

All head loss tests performed by DCPP developed a thin fiber bed over a portion of the strainer. However, none of these "thin beds" involved all of the surface area of the strainer. The resolution path for acceptable head loss was to ensure that the portion of the strainer without a fiber bed did not get overwhelmed by coatings chips to the point that the chemicals were filtering out on the coatings chip beds.

Testing has shown some areas where coatings chips are sufficiently concentrated to allow filtering of chemicals, but due to the reduction in unqualified coatings chips (by limiting plant margin for unqualified coatings, and reducing transport fractions through the performance of debris interceptor testing) there are also significant areas (on the order of 10 percent or more) that are essentially void of coatings chips (Tests 14-S-PSG and 15-S-PSG). From the testing performed by DCPP, there is reasonable assurance that the fiber beds and coatings chip beds on our strainer (the filtering beds) are not large enough to result in strainer failure (will not cause too high a head loss) for any of the analyzed breaks. We have sufficiently tested our limiting breaks, and by properly addressing potential debris sources (fiber, calcium silicate, unqualified coatings chips, particulate, latent debris, and chemical effects), have achieved acceptable head loss results.

DCPP has also demonstrated through testing the ability to back-flush the strainer in the beyond design basis event that the strainer becomes completely obstructed by a debris bed.

<u>Vortexing</u>

The minimum water level in containment at the start of transition to recirculation was calculated to be at an elevation of 92.8 ft for the limiting small-break LOCA case, and an elevation of 93.6 ft for the large-break LOCA case. The floor of containment is located at elevation 91 ft, thus, the minimum pool depth is 1.8 ft for a small-break LOCA and 2.6 ft for a large-break LOCA. For the large-break case and some small-break LOCA cases, the water level will continue to rise to a level above the top of the strainers. The top of the strainers is at elevation 93.6 ft. A schematic of the ECCS system is given in Figure 22.

The potential of the strainers to vortex was evaluated separately for large-break and small-break LOCA conditions. The susceptibility to vortexing was evaluated by test in both cases.

Large-break LOCA Vortexing

The most limiting large-break LOCA conditions occur at the initiation of switchover to cold-leg recirculation. At this time, the highest RHR pump suction flow is experienced, and the sump water level is just covering the strainers. Water level will continue to rise due to the continued operation of the CS, SI and centrifugal charging pumps.

As a part of the acceptance testing of the DCPP strainers, a vortexing test was performed on a full-size screen module to examine the limiting case. A test module was tested in a pool at full flow conditions. Testing was conducted with the water depth over the strainers similar to the plant configuration. No vortexing or air entrainment was observed during testing.

At the conclusion of the Test 3-S-ECE with a fully debris-laden front sector, the pool water level and flow rate were reduced. No vortexing or air ingestion was observed. At the conclusion of a rear module head loss test, the water level was lowered. Vortexing was first observed after a 39-inch drop in the water level (only 9.5 inches was submerged of the 48.5-inch high module).

The plant strainers are designed such that they are completely submerged under water at the start of recirculation after a large-break LOCA. This is considered a fully-submerged screen configuration. For fully-submerged sump screens, sump failure (i.e., pump cavitation) occurs when the head loss across the debris bed equals or exceeds the NPSH margin. The NPSH margin has not been exceeded by head loss across the bed, nor by total strainer head loss; therefore, sump failure and resulting pump cavitation is not predicted.

Strainer testing on another nuclear power plant experienced air entrainment for thick circumscribed debris beds. The fiber accumulated above the test strainer and reached the water's surface, and air was pulled through the fiber bed into the strainer. DCPP has demonstrated that plant debris loads are not capable of forming even a "thin bed" over the entire surface area of the strainer so there is no possibility of a circumscribed bed being formed.

All of the analyzed breaks have been evaluated for debris generation. As discussed in head loss testing, the results of these analyses and tests show that the DCPP strainers are adequate to preclude the formation of a "thin bed" over the entire screen area (i.e., only a partial "thin bed" forms on the strainer). DCPP has taken a number of actions to assure acceptable strainer performance. The actions have included consideration of screen sizing, a number of debris removal modifications, installation of debris interceptors, and strainer head loss testing. These actions have provided reasonable assurance that there will be some clean area on the DCPP strainers for all breaks, and this has been demonstrated through testing.

The results of this testing demonstrated that the DCPP strainer design is capable of operating under full flow conditions after a large-break, design basis LOCA without generating a vortex which would result in the entrainment of air into the strainers and the ECCS system.

Small-break LOCA Vortexing

The small-break LOCA evaluation required the evaluation of a number of different conditions due to the design of the strainers. Since the small-break LOCA scenarios may result in a partially-submerged strainer, additional evaluation of the strainer system was conducted. Partial submergence of the strainers results in a condition where an air-water interface would exist within the upper plenum and descending elbows in the front strainer assemblies as seen in Figure 23. The presence of this air-water interface, when coupled with flow direction changes and a descending elbow, was considered to be highly susceptible to vortexing. As a result, a separate set of small-break LOCA-specific tests was performed to evaluate susceptibility.

The testing performed evaluated the vortexing at expected flow rates on a full-sized plenum and descending elbow. This testing confirmed vortexing under the postulated conditions, and a set of flow straighteners was added to reduce the tendency to vortex and to eliminate air entrainment as a concern. The modifications were tested in the same mockup with successful results. These tests established that the performance of the DCPP strainers at water levels representative of a small-break LOCA would not result in conditions which would entrain excessive amounts of air into the suctions of the RHR pumps.

Flashing Evaluation

The minimum margin to prevent post-LOCA flashing downstream of the DCPP strainers is 468.07 inches of water (16.91 pounds per square inch differential [psid]) based on an onset of recirculation at 18.5 minutes (1110 seconds) after the start of the LOCA and a containment pressure of 14.7 pounds per square inch absolute (psia). For containment pressure at 13.7 psia, which would represent a limiting condition allowed in the Technical Specifications, the flashing margin would be 440.37 inches of water (15.91 psid). The maximum sump water temperature where saturation pressure is the highest occurs at 20 seconds which is prior to the onset of recirculation and is therefore not applicable to this conclusion. The flashing margin is much greater than the allowable strainer and plenum head loss of 41 inches of water. Based on this, there is no potential for flashing anywhere in the DCPP strainer.

The analysis assumes saturation conditions, containment air pressure as noted in the paragraph above, and no air pockets in the strainer. The DCPP Units 1 and 2 strainer structures have been designed to preclude the formation of any air pockets of significant size. This aspect of the design ensures that there will be no locations within the strainer structure where air could accumulate into a pocket where local pressure conditions could result in conditions which would lead to flashing.

Figures

Figure 1: Sector Test Setup Schematic (Temperature was Maintained Using A Heating or Cooling Coil As Needed)

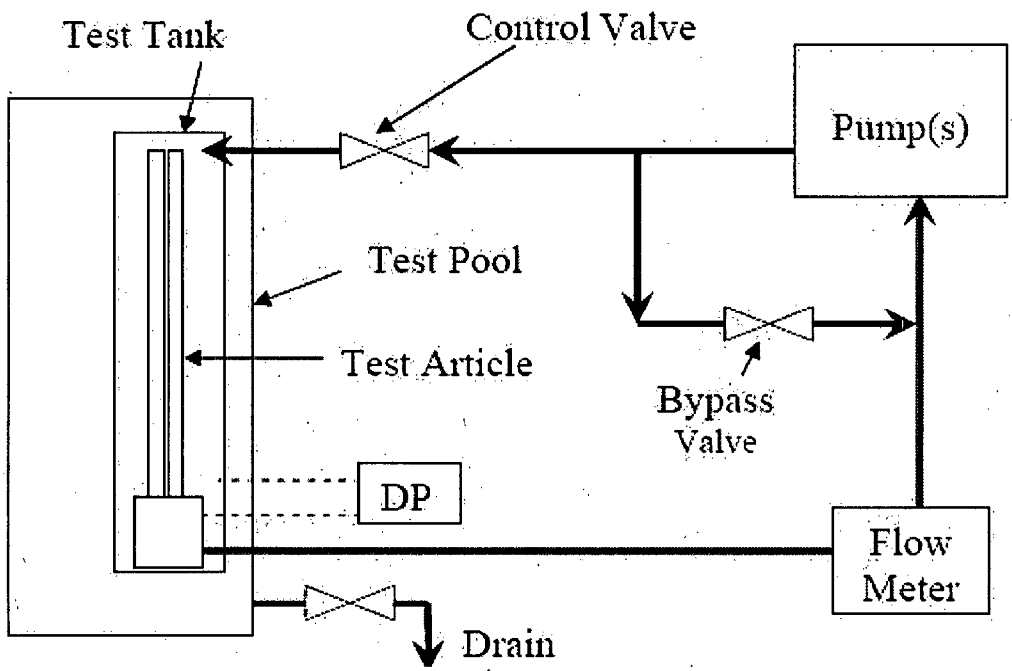


Figure 2: Module Test Setup Schematic

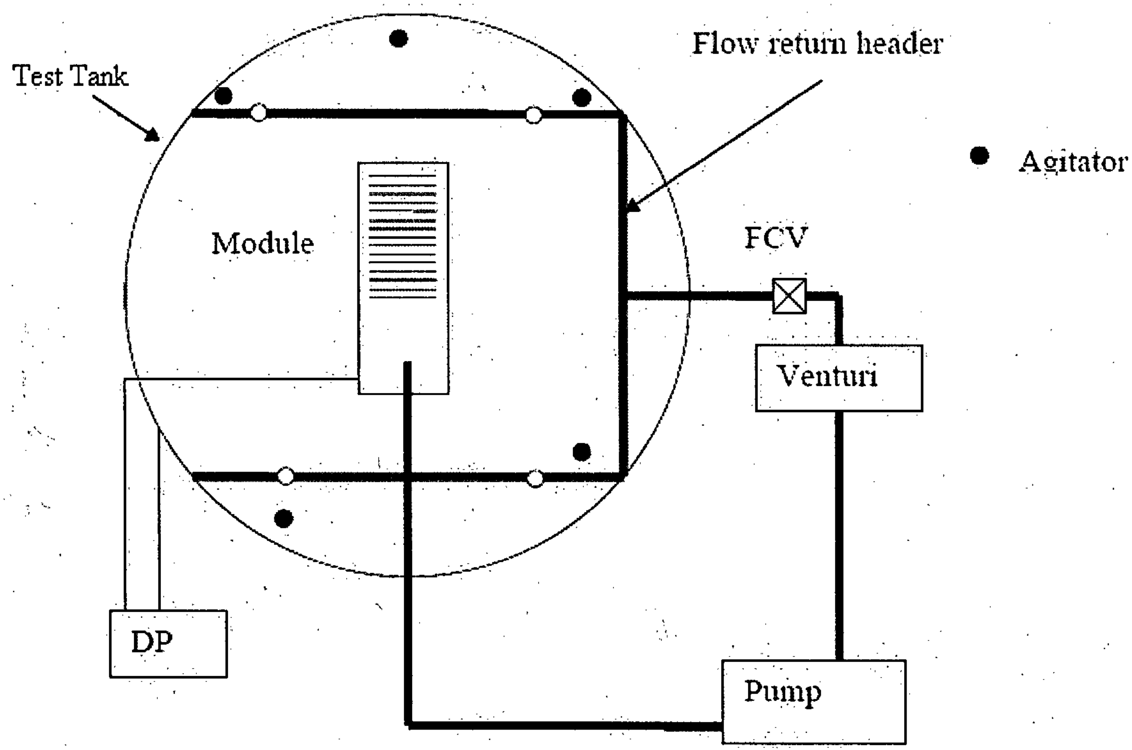


Figure 3: Fiber Bypass Test Setup Schematic

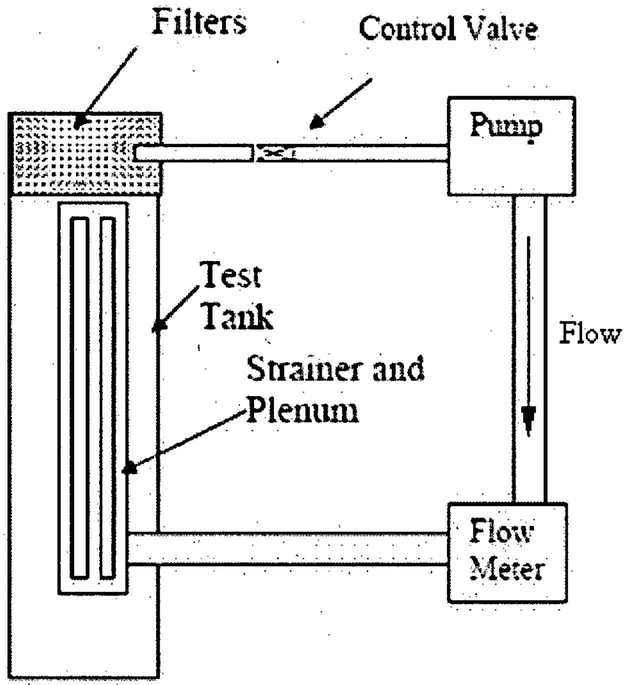


Figure 4: Fuel Bottom Nozzle Test Setup Schematic

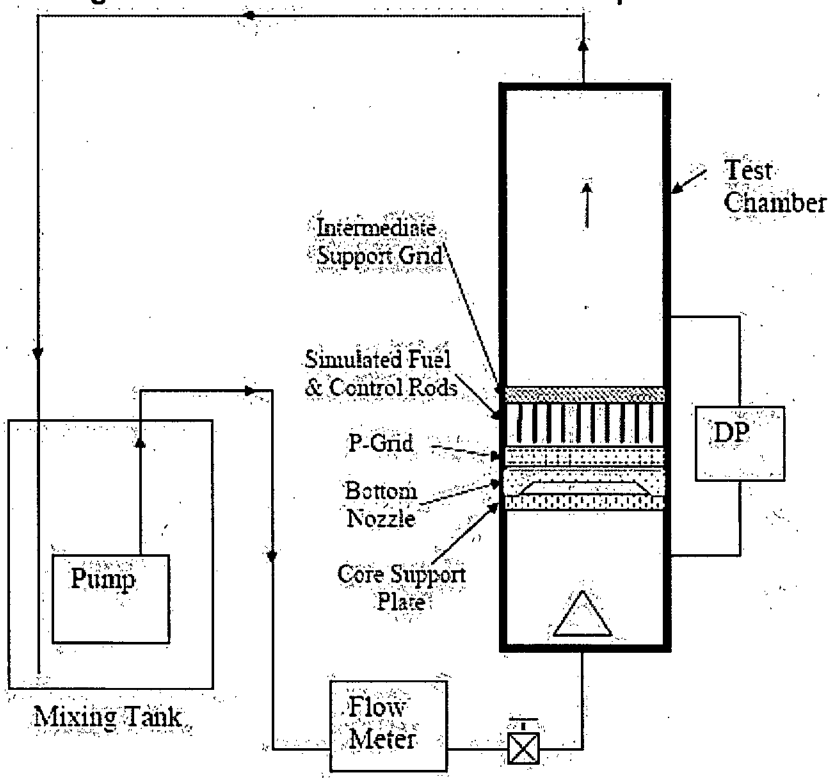


Figure 5: Fuel Bottom Nozzle Test Setup Photo

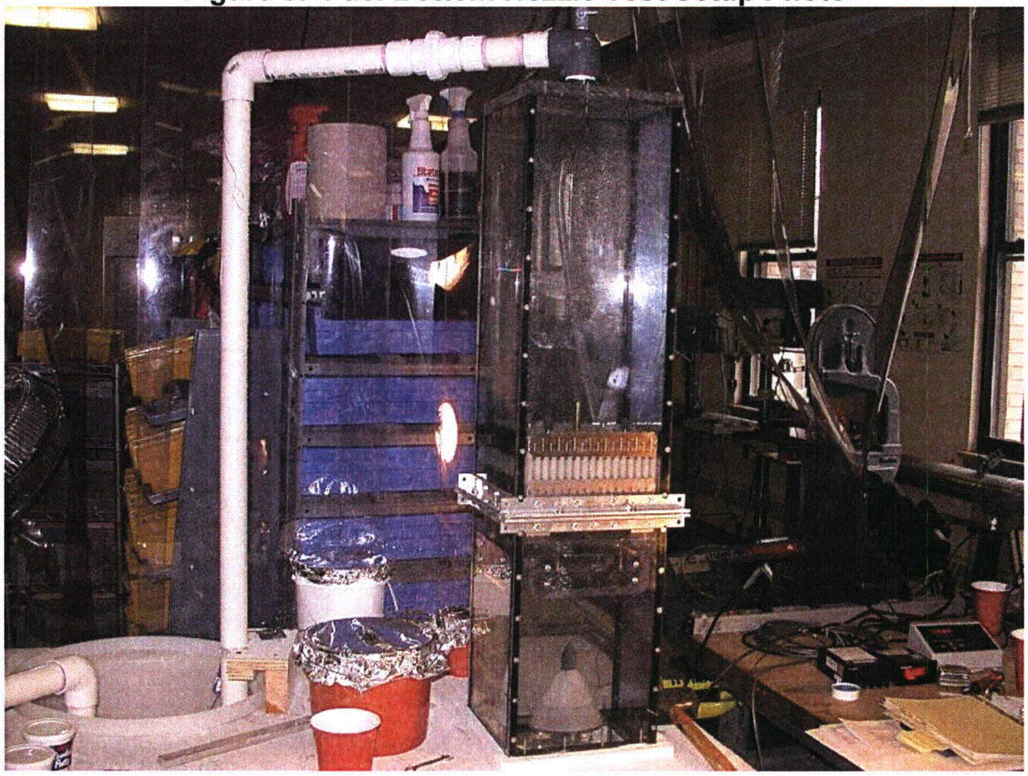


Figure 6: Aluminum Oxyhydroxide Turbidity Plot

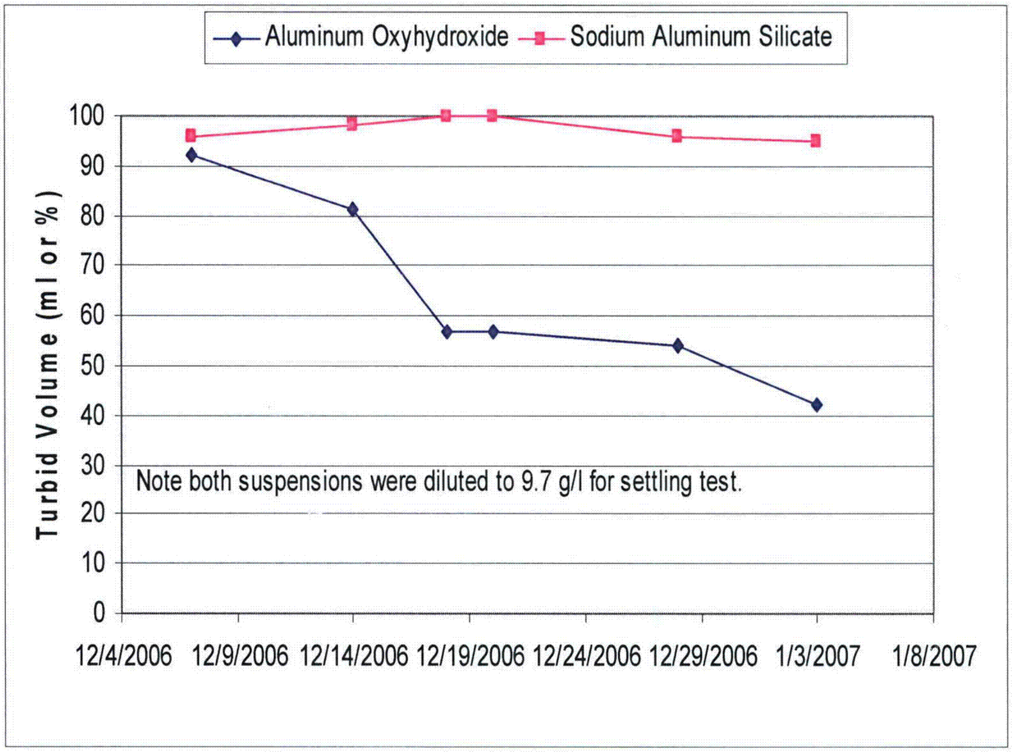


Figure 7: 8-S-PSG, 9-S-PSG, and 10-S-PSG Head Loss Plots

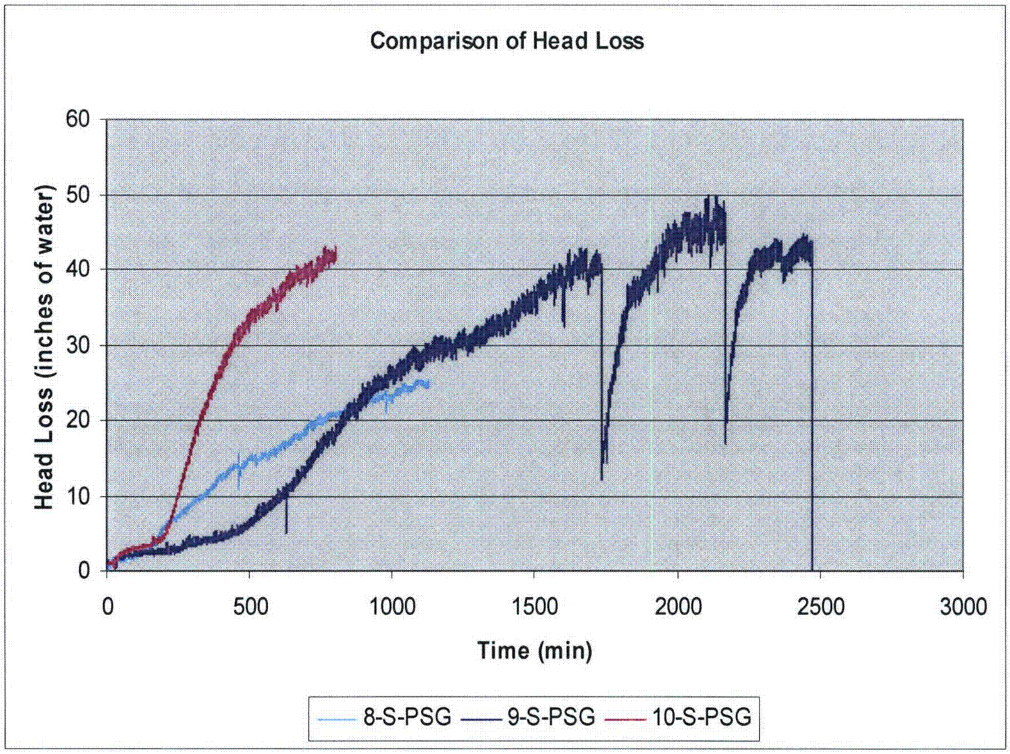


Figure 8: Sector Head Loss Test 8-S-PSG Test Sector Photo (Plenum Was on the Left)

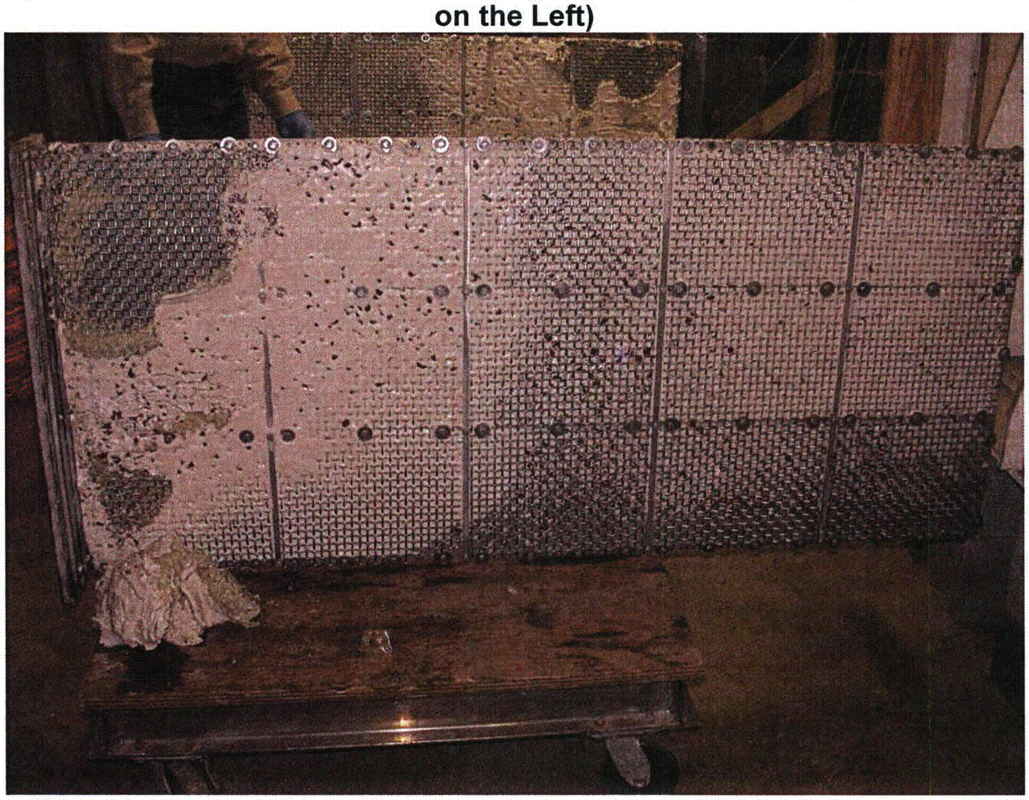


Figure 9: Sector Head Loss Test 9-S-PSG Test Sector Photo 1 (Plenum Was on the Left)

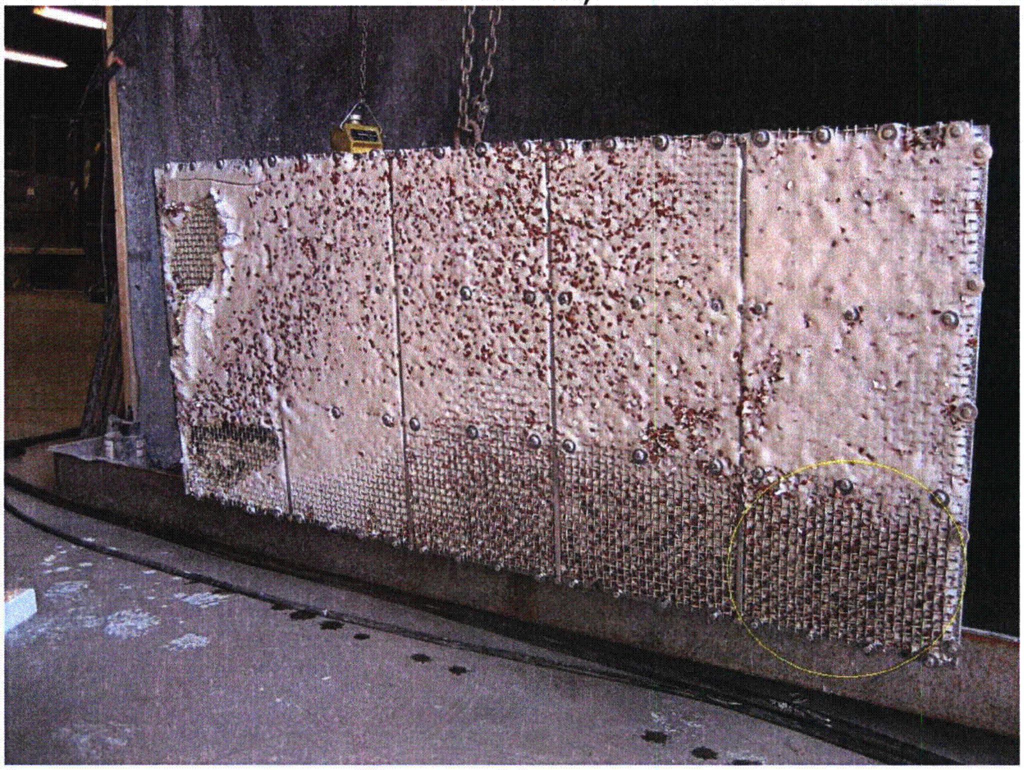


Figure 10: Sector Head Loss Test 9-S-PSG Test Sector Photo 2 (Closer View of Area Indicated in Yellow Above)

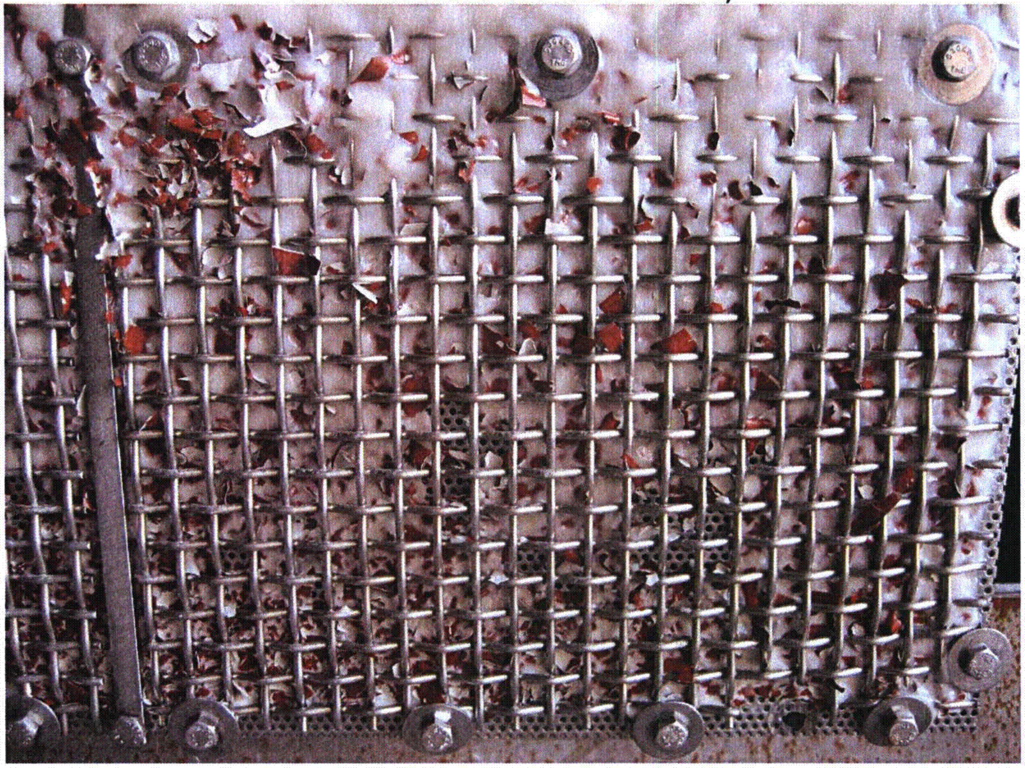


Figure 11: Sector Head Loss Test 10-S-PSG Test Sector Photo 1 (Plenum was on the Left)

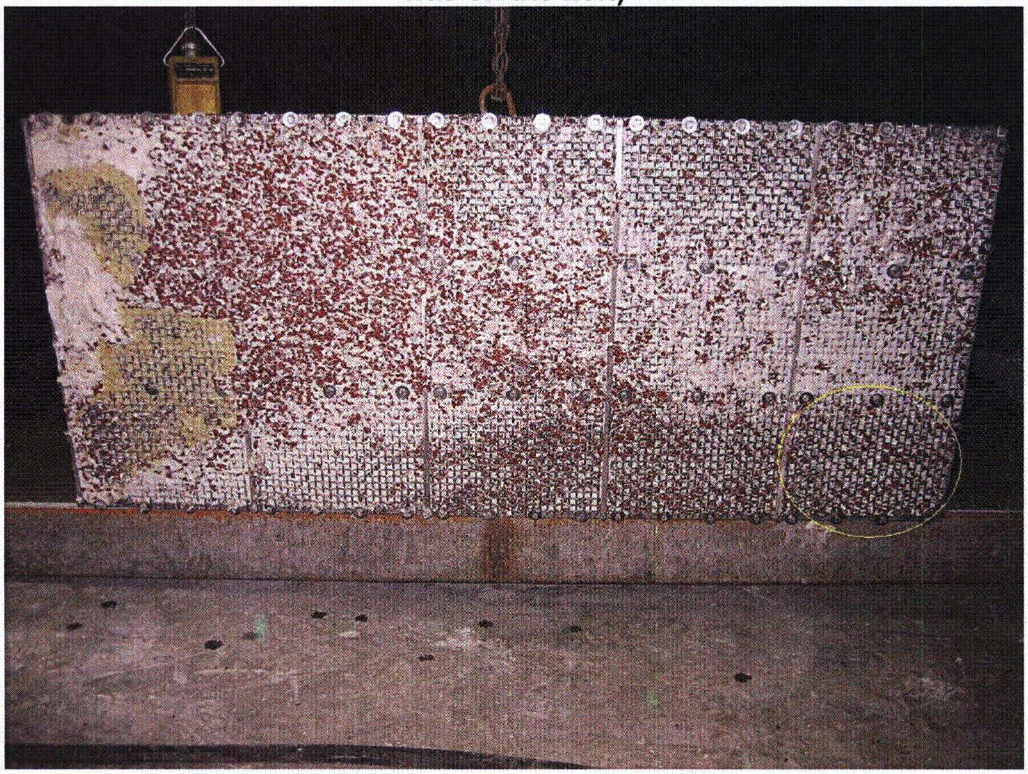


Figure 12: Sector Head Loss Test 10-S-PSG Test Sector Photo 2 (Closer View of Area Indicated in Yellow Above)

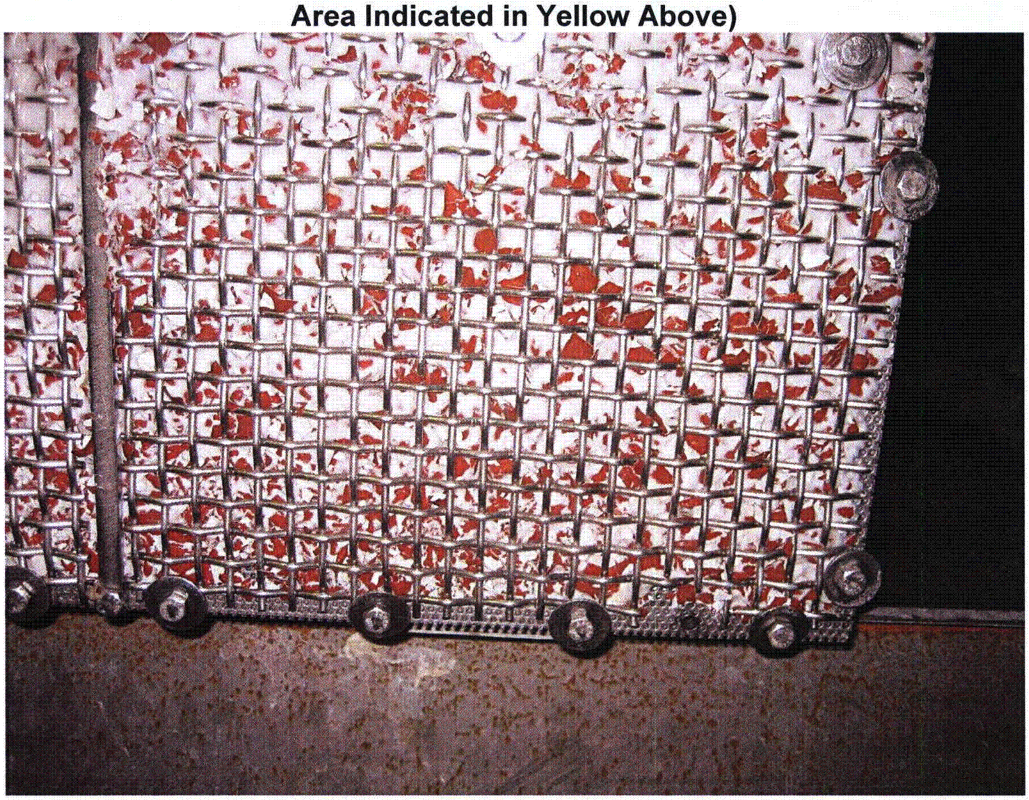


Figure 13: Sector Head Loss Test 11-S-PSG Test Sector Photo 1 (Plenum was on the Left)

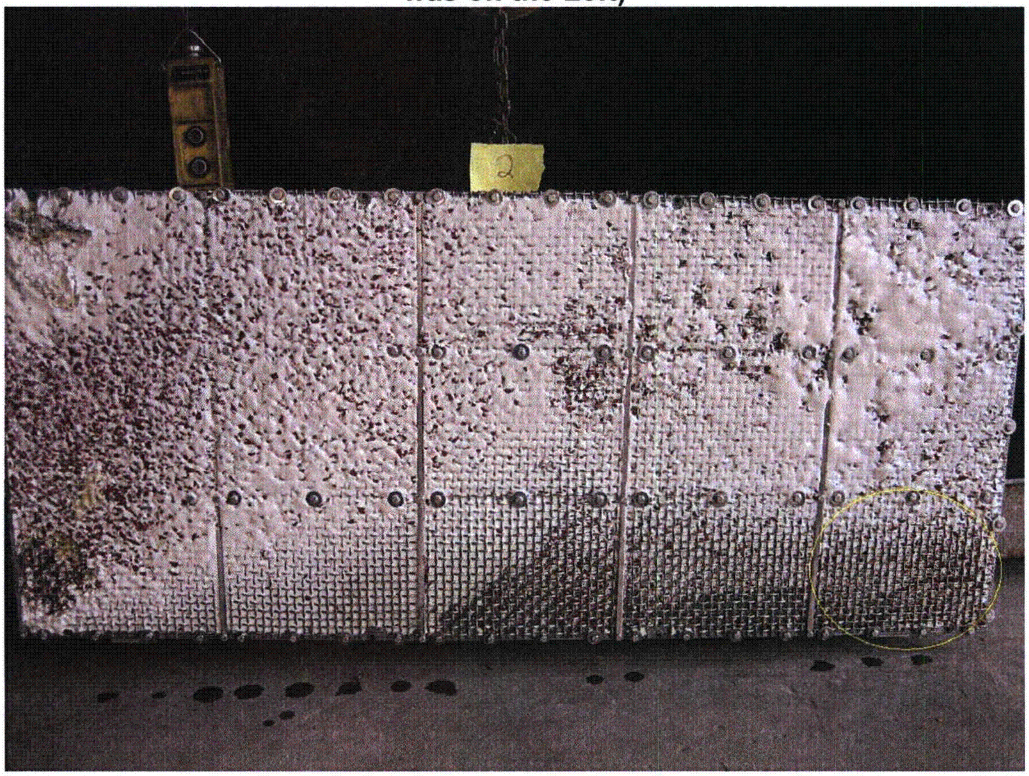


Figure 14: Sector Head Loss Test 11-S-PSG Test Sector Photo 2 (Closer View of Area Indicated in Yellow Above)

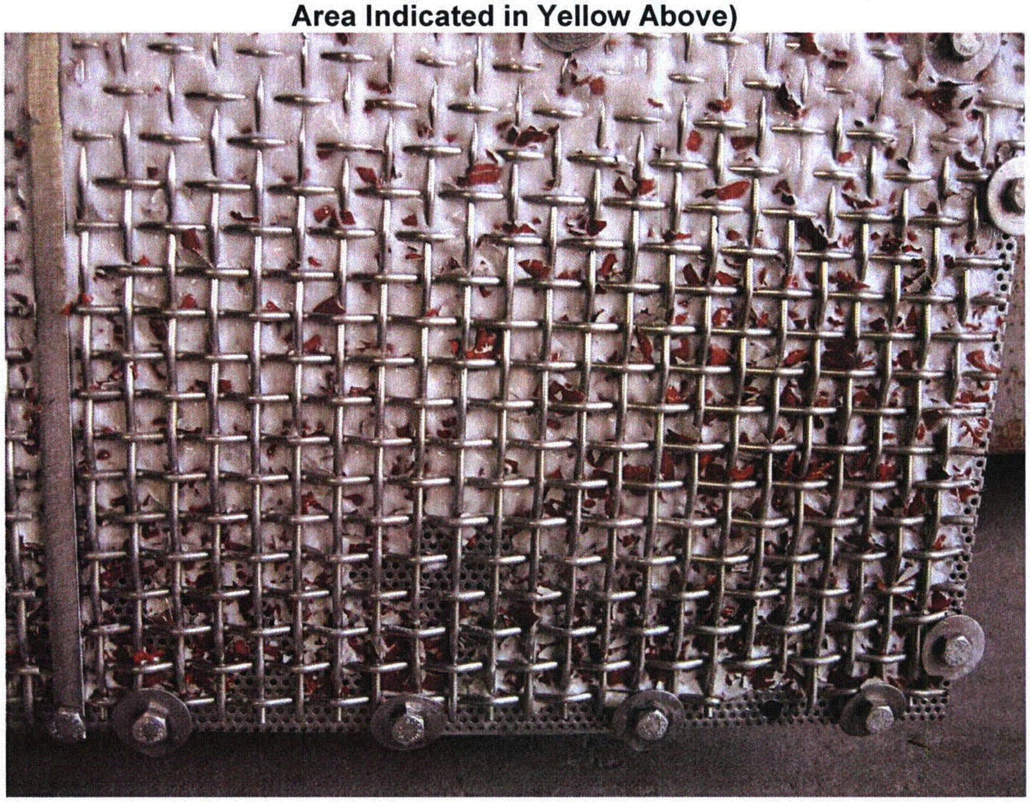


Figure 15: Sector Head Loss Test 12-S-PSG Test Sector Photo 1 (Plenum was on the Right)

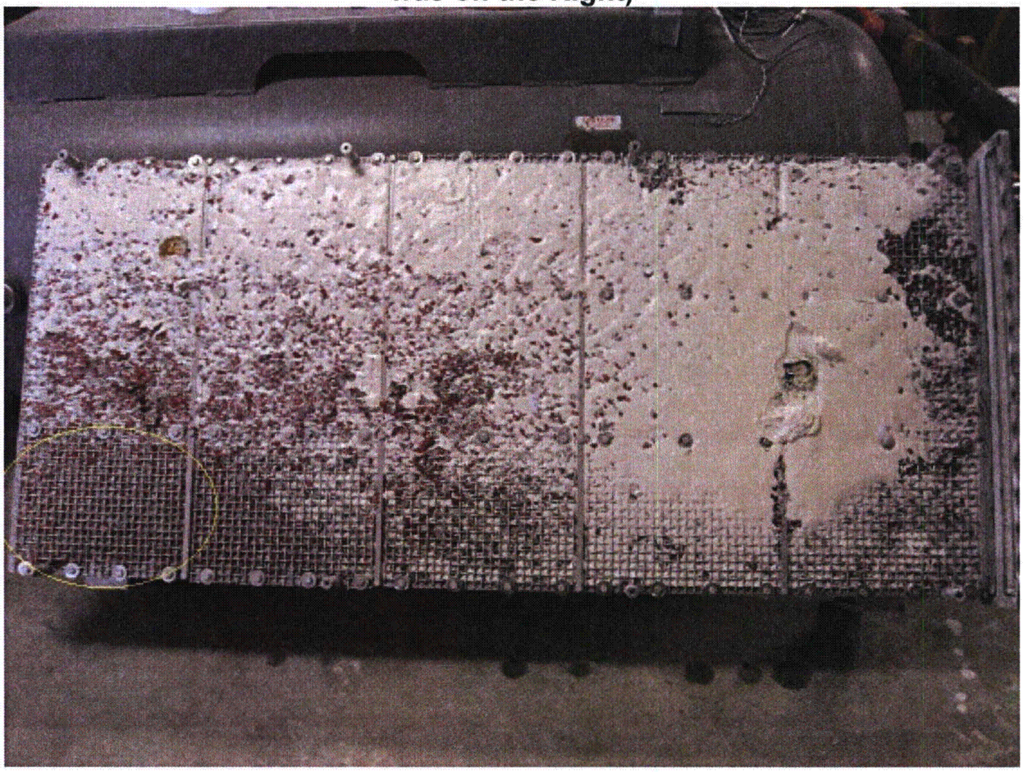


Figure 16: Sector Head Loss Test 12-S-PSG Test Sector Photo 2 (Closer View of Area Indicated in Yellow Above)

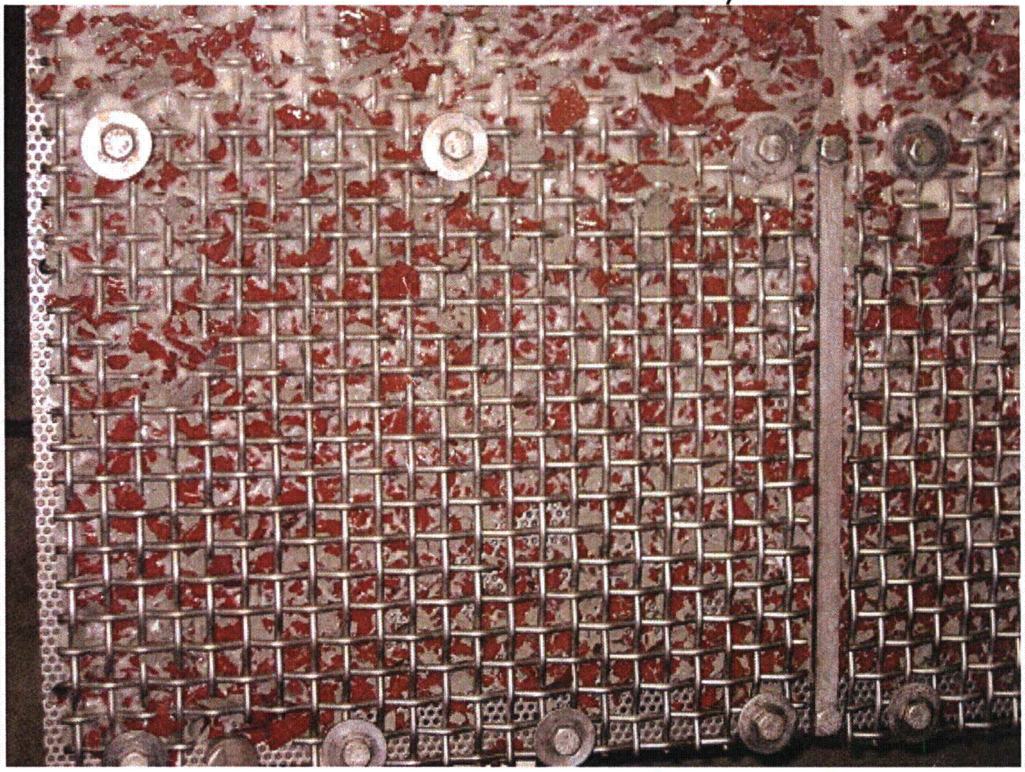


Figure 17: Sector Head Loss Test 14-S-PSG Test Sector Photo 1 (Plenum was on the Right)

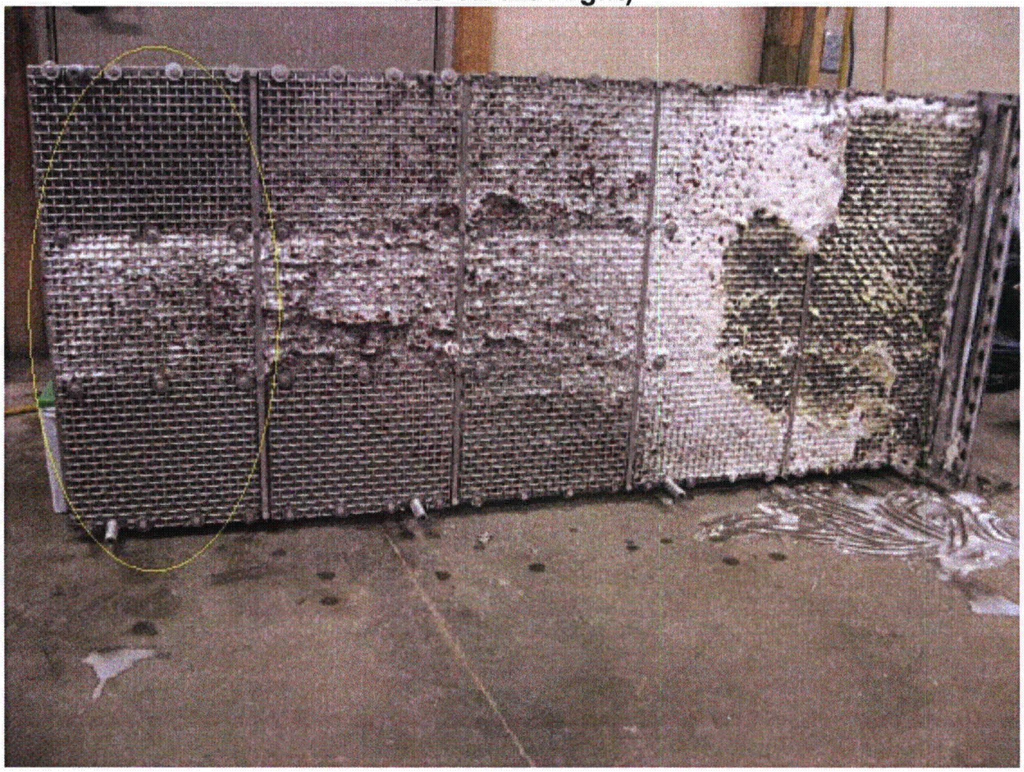


Figure 18: Sector Head Loss Test 14-S-PSG Test Sector Photo 2 (Closer View of Area Indicated in Yellow Above)

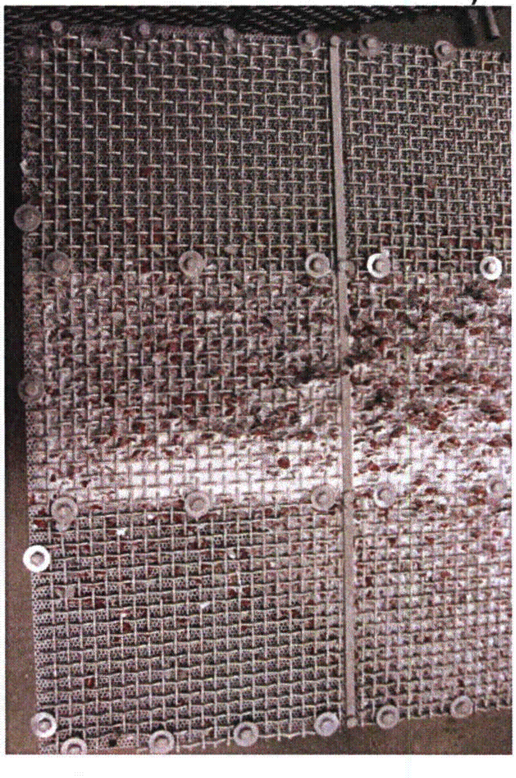


Figure 19: Sector Head Loss Test 15-S-PSG Test Sector Photo 1 (Plenum was on the Right)

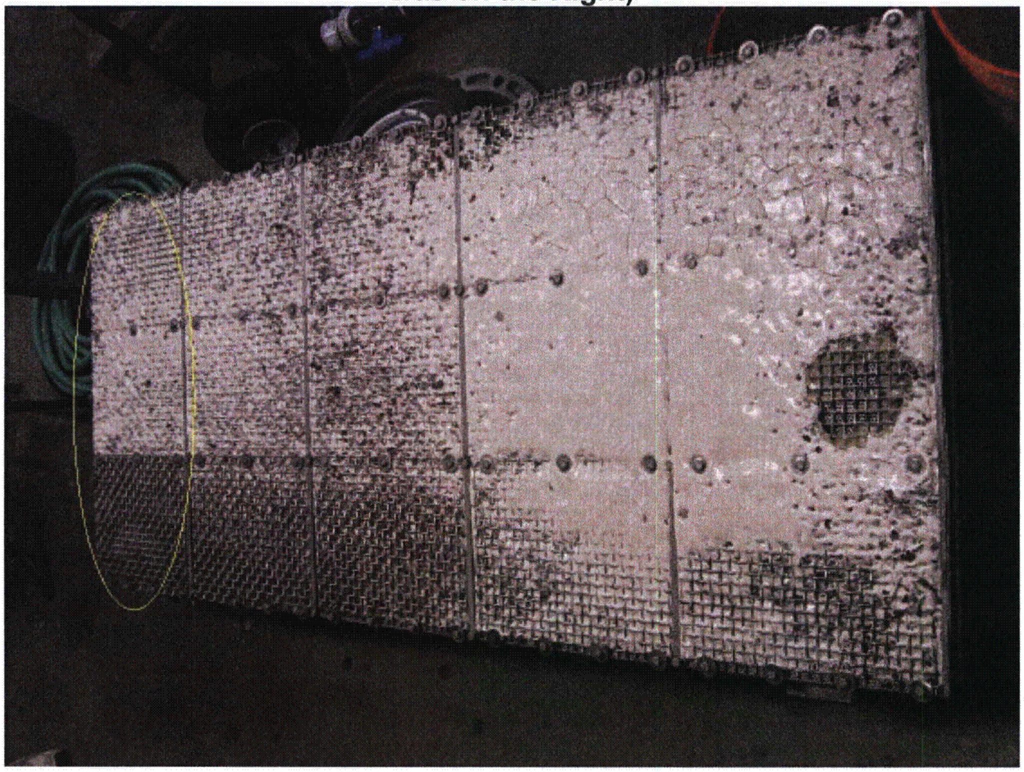


Figure 20: Sector Head Loss Test 15-S-PSG Test Sector Photo 2 (Closer View of Area Indicated in Yellow Above)

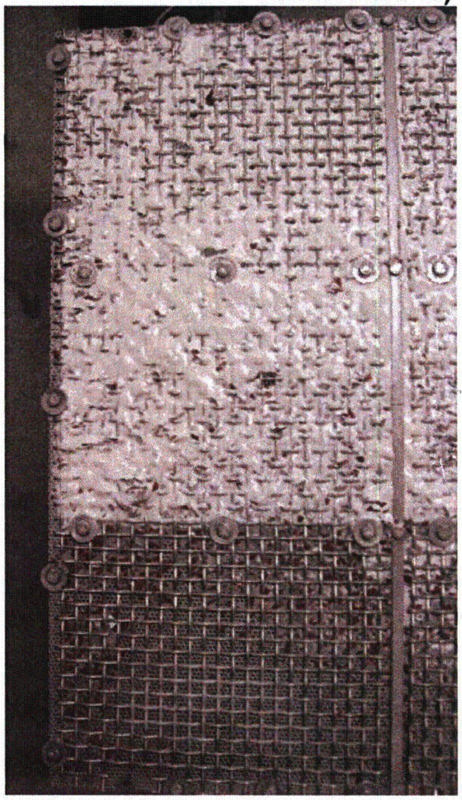


Figure 21: 11-S-PSG, 12-S-PSG, 14-S-PSG, and 15-S-PSG Head Loss Plots

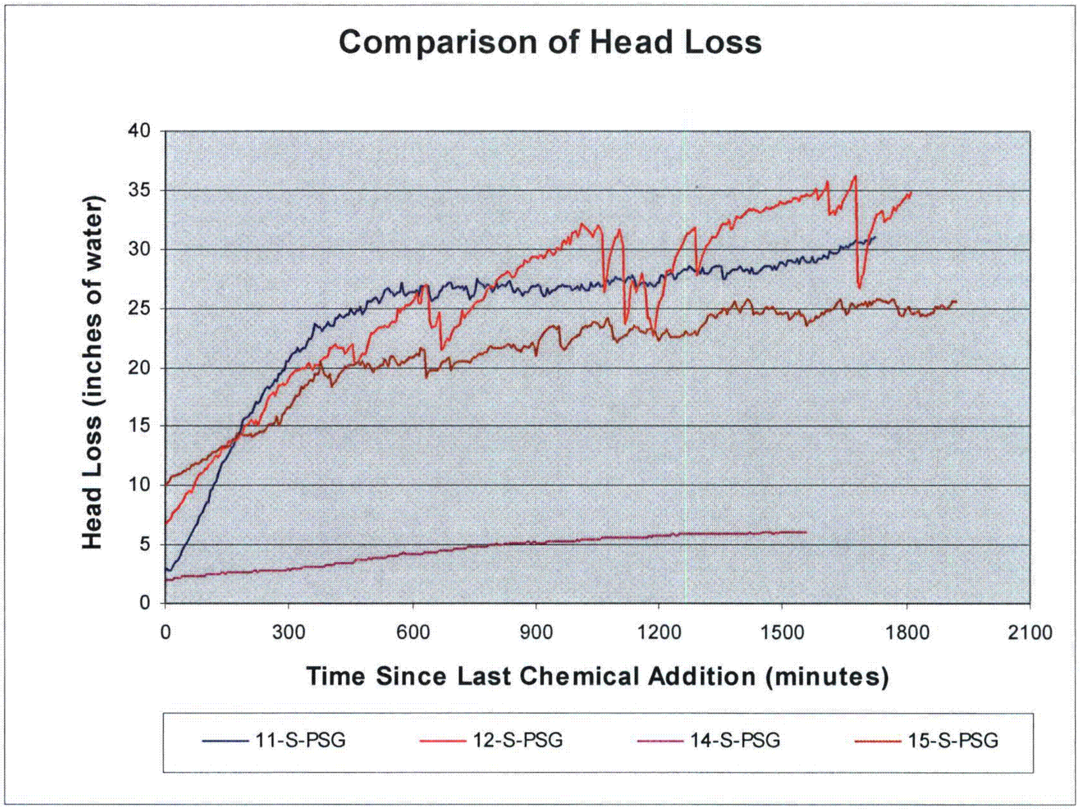


Figure 22: ECCS Schematic (Cold-leg Recirculation Shown)

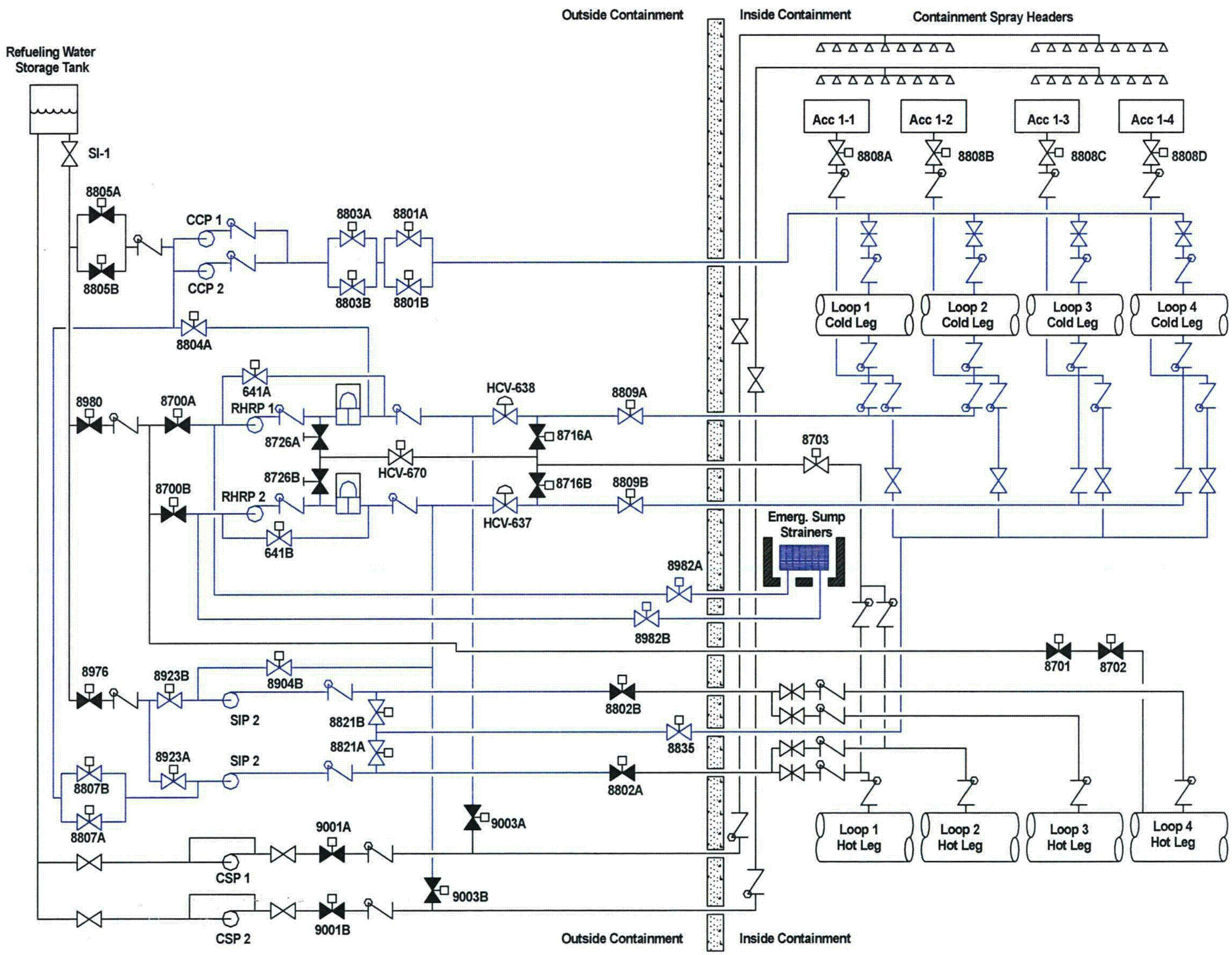
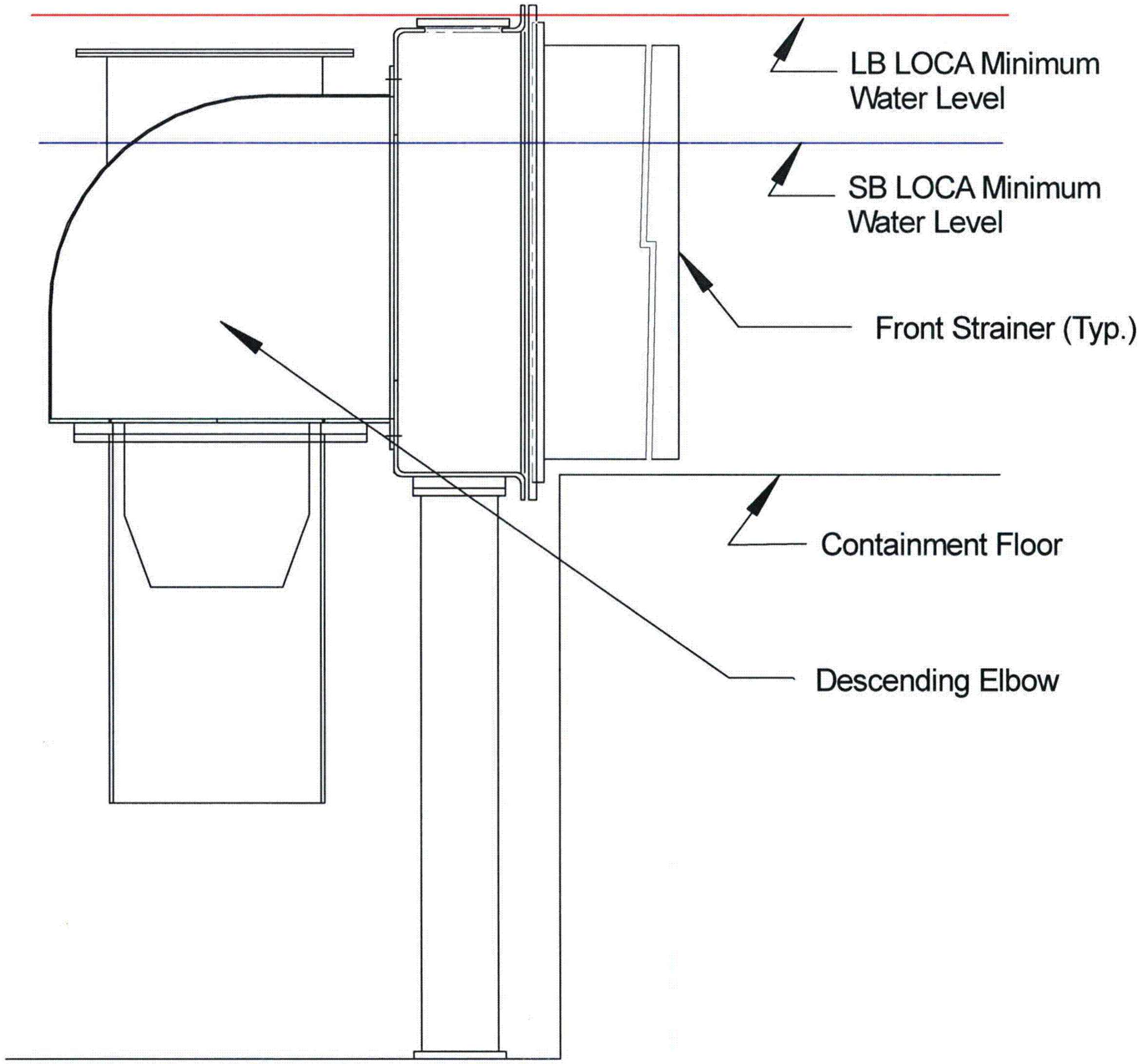


Figure 23: Strainer Partial Submergence Diagram



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.

- *Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level.*
- *Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions.*
- *Provide the basis for the required NPSH values, e.g., three percent head drop or other criterion.*
- *Describe how friction and other flow losses are accounted for.*
- *Describe the system response scenarios for LBLOCA and SBLOCAs.*
- *Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation.*
- *Describe the single failure assumptions relevant to pump operation and sump performance.*
- *Describe how the containment sump water level is determined.*
- *Provide assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin.*
- *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.*
- *Provide assumptions (and their bases) as to what equipment will displace water resulting in higher pool level.*
- *Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source.*
- *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.*
- *Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature.*
- *Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.*
- *Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.*

<u>PG&E Response:</u>

The DCPP engineered safety feature systems include two trains of ECCS pumps and two trains of CS pumps. Each ECCS train consists of one high-pressure injection pump (a centrifugal charging pump [CCP]), one intermediate-pressure injection pump (one safety injection pump [SIP]), and one low-pressure injection pump (an RHR pump). The SIPs, RHR pumps, and the CS pumps are normally aligned to the RWST. The CCPs are realigned to the RWST on an SI signal. The ECCS trains are realigned to the containment recirculation sump by manual operator actions once the water level in the RWST reaches 33 percent.

System response is determined by break size and resulting RCS and containment pressure characteristics. The ECCS pumps are actuated by a SI signal. An automatic SI signal is generated when RCS pressure decreases to 1850 pounds per square inch, gauge (psig) or when containment pressure reaches 3 psig or when main steam line pressure drops below 600 psig. Similarly, the CS pumps are actuated when containment pressure increases to 22 psig. CS actuation may not occur for all loss of coolant accidents.

Due to the relatively low shutoff head of the RHR pumps, RHR flow to the RCS will not begin until the RCS depressurizes to approximately 170 psig. For a large-break LOCA, rapid RCS depressurization and concurrent containment pressurization will result in ECCS and CS actuation early in the event. For the bounding large-break LOCA, RCS pressure will be sufficiently low to allow full ECCS flow, resulting in most rapid depletion of the RWST and therefore, earliest switchover to ECCS sump recirculation.

For both small-break and large-break LOCAs, an RHR trip is generated when RWST level decreases to a predetermined level of 33 percent. Transfer to ECCS recirculation is then accomplished by opening the containment recirculation sump suction valves and closing the RWST suction valves. Both RHR pumps take suction from the common containment recirculation sump. The CCPs and SIPs are then aligned to take suction from the RHR pump discharge (piggyback operation). CS system operation is not required during recirculation modes, therefore, no NPSH evaluations are performed for the CS pumps during recirculation. NPSH acceptance criteria are based on the required NPSH specified by the pump vendor.

NPSH calculations were performed to establish the ECCS NPSH margin in the absence of the ECCS strainers and collected debris (i.e., pump NPSH margins were calculated by subtracting the NPSH available from the NPSH required, without including head loss through the ECCS strainer and collected debris). The NPSH calculations establish piping flow resistances in accordance with hydraulic methods based on Crane Technical Paper No. 410, and the flow resistance of the discharge piping from the RHR pump back into the RCS are based on actual benchmarked piping losses.

Since the NPSH requirements for a small-break LOCA are substantially lower than the requirements for a large-break LOCA and the minimum containment water level at the start of recirculation after a small-break LOCA is close to that of the large-break LOCA, the results of the large-break LOCA are considered to be bounding and no additional NPSH analysis was performed for the small-break LOCA.

The design basis NPSH analyses assume that pumps are operating at their maximum flow rates. The calculations addressed both cold-leg recirculation conditions and hot-leg recirculation and included the calculated head loss from the new sump strainers. The most limiting active failure for each case was failure of the other RHR pump and was considered in the determination of the worst-case pump flow conditions. The results of the NPSH calculations are reported in Table 1 below for both cold-leg and hot-leg recirculation cases. Since the CCP and SIP suction pressures are boosted by the RHR pump discharge pressure, only the RHR pumps take suction directly from the ECCS sump, and only the RHR pump NPSH values are reported. The minimum NPSH margin is 1 ft. for RHR Pump No. 1 and occurs during hot-leg recirculation.

Table 1

Pump	Case	Flow (gpm)	NPSHA (ft)	NPSHR (ft)	NPSH Margin (ft)
RHRP1	Cold-leg Recirculation	4542	24.5	19	5.5
RHRP2	Cold-leg Recirculation	4309	24.2	18	6.2
RHRP1	Hot-leg Recirculation	4891	25	24	1.0
RHRP2	Hot-leg Recirculation	4699	28	21	7.0

Results in Table 1 include head loss across the debris-laden ECCS strainer during the recirculation mode of emergency core cooling system following a postulated LOCA.

The available NPSH calculations were performed using assumptions more conservative than the guidance in NEI 04-07. For the NPSH margin calculations, no subcooling due to containment pressure was credited (i.e., containment pressure was assumed to equal the vapor pressure corresponding to the sump water temperature).

Strainer head loss calculations were performed assuming a flow corresponding to two-train operation (maximum flow through the strainer of 7769 gpm) and a sump temperature of 100°F to maximize the head loss in the strainers. Colder temperatures were determined to be the most limiting due to the effects of increased water viscosity and the corresponding flow resistance across the sump screens. Strainer hydraulic performance was established through an evaluation of the flowpaths within the strainer. Flow resistance was evaluated using methodologies from Crane Technical Paper No. 410 and the Handbook of Hydraulic Resistances by Idelchik. As a result, the NPSH calculation used a conservative net head loss of 41 inches for the sump strainer assembly (33 inches for the strainer screen and 8 inches for the strainer plenum).

The minimum water level in containment at the start of transition to recirculation was calculated to be at an elevation of 92.8 ft for the limiting small-break LOCA case, and an elevation of 93.6 ft for the large-break LOCA case. The floor of containment is located at elevation 91 ft, thus, the minimum pool depth is 1.8 ft for a small-break LOCA and 2.6 ft for a large-break LOCA.

The switchover to ECCS recirculation begins when the RWST is depleted to approximately 33 percent. ECCS cold-leg alignment to recirculation is complete when both ECCS trains are taking suction from the sump. During the switchover to recirculation, the containment water level will continue to increase above the initial 93.6 ft elevation due to continued operation of the CS pump(s), and the CCPs and SIPs. Containment water level at the completion of realignment to cold-leg recirculation was calculated to be 93.9 ft. The CS pumps continue to take suction from the RWST until the 4 percent low-low water level alarm is reached. At this time, the containment water level is calculated to be at least 94.5 ft.

The water level calculation conservatively accounts for the sources of water on the containment floor and for the water holdup mechanisms and associated volumes.

The conditions considered that could reduce the water contribution to the sump are:

- Remaining liquid volume in the RCS
- RCS shrinkage due to cooling, requiring RWST makeup
- Partial to zero accumulator discharge (RCS pressure above 600 psig)
- Water vapor retained in the containment atmosphere
- Liquid condensation and pooling on containment and component surfaces
- Water in transit from the break to the sump
- Water volume required to fill the CS piping
- RWST leakage
- RWST level errors and uncertainties

The inputs to the water level calculation are biased toward minimizing the containment water level. The calculation uses the reactor coolant system, the RWST, the accumulators (if RCS pressure drops below 600 psig) and the spray additive tank (SAT) as water sources. The RWST is assumed to initially be at the TS minimum level, and as the injection phase proceeds, the level is assumed to drop to the low-low level alarm setpoint, at which point the switchover to cold-leg recirculation begins. The total volume of water injected from the RWST is 29,362 cubic feet. Each of the accumulators is assumed to be at the TS minimum level, and the volume of water added to the containment floor from the accumulators is determined based on the case evaluated (large-break LOCA, etc.) and can be up to 3379 cubic feet. The SAT contribution is determined based on spray system operation time and eductor performance and can be up to 238 cubic feet.

The water level calculation assumes that structural components will displace water, resulting in a higher pool level. These structural components include the primary shield wall, the crane wall (including the straight sections of the wall and the refueling cavity support walls), the RCP and SG pedestals, support structures for the pressurizer relief tank, and permanent obstructions in the annulus. Volumes below the containment floor level are determined based on the air volume in the cavity below the reactor and the associated passages to the cavity from the reactor coolant drain tank room and the incore instrumentation tunnel.

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.

- *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.*
- *Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.*
- *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.*
- *Provide bases for the choice of surrogates.*
- *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.*
- *Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.*
- *Describe any ongoing containment coating condition assessment program.*

<u>PG&E Response:</u>

- *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.*

The coating systems used in Unit 1 and Unit 2 containments at DCPP are similar with minor variances in coating types and quantities based on plant needs.

The main qualified coating system used in both containments is the inorganic zinc (IOZ)/epoxy coating system, which includes Carboline CZ11/Phenoline 305 and Carboline CZ11/190HB, for steel substrate and epoxy coating system for concrete surfaces that includes Ameron Nuklad 108 and Amercoat 66.

Other qualified coatings such as Carboline 890 and Keeler & Long 4500 have been used for steel.

The large part of unqualified coating systems found in Unit 1 is the organic zinc rich epoxy (OZ)/alkyd/epoxy system, (Triangle H197/Triangle T-50/Carboline Phenoline 305) and IOZ/alkyd/epoxy system (Carboline CZ11/ Triangle T-50/Carboline Phenoline 305) in Unit 2.

- *Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.*
- *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.*
- *Provide bases for the choice of surrogates.*
- *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.*

- *Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.*

The assumption made for coatings in the zone of influence of the LOCA is based on testing performed on representative coating systems. A spherical ZOI of 5D was selected based on WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA Qualified/Acceptable Coatings," Revision 0, dated June 2006. In addition, a Zone of Influence Evaluation for DBA Qualified Coatings at DCPP was performed using the results of the Coatings Performance Tests conducted at Plant St. Lucie. This evaluation also concluded that a spherical ZOI of 5D is conservative for DCPP.

For transport analysis, 10 micron particles were assumed for qualified coatings within the 5D ZOI. Qualified coatings outside the 5D ZOI were not assumed to fail.

The total concrete and steel surface area within this ZOI was calculated using the DCPP CAD model. The major steel and concrete structures are considered to be well represented within the CAD 3-D containment model. A break at each of the four loops was postulated, with the break location at the midpoint of the crossover leg. The surface areas within the ZOI were similar for each loop. The concrete and steel surface areas were conservatively estimated to be 736 ft^2 and 802 ft^2, respectively, within the 5D ZOI.

Additional coatings terms associated with items such as pipe hangars, non-insulated piping and access platforms were conservatively accounted for by adding an additional 20 percent to the steel surface areas (for a total steel area of 963 ft^2). The resultant total surface area within the ZOI estimate is 1700 ft^2.

For unqualified coatings outside the 5D ZOI, the quantity and size of the particles were based on testing.

Degraded qualified epoxy coatings outside the ZOI are assumed to fail as chips, with a size characteristic dependent upon coating thickness. Section 3.4.3.6 of the NEI methodology recommends that unqualified epoxy coatings outside the ZOI fail as particulate with a diameter of 10 microns. However, the 10-micron size is associated with erosion of coatings due to high pressure jet impingement inside the ZOI. Coatings outside the ZOI will not be exposed to jet impingement, and therefore, the predominant failure mechanism will not be erosion. The NRC staff has agreed that this is a reasonable assumption in Crystal River Letter to the NRC dated August 30, 2005, "Crystal River Unit 3 -Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors.'" The degraded qualified coatings will contribute to the total debris source term in a fashion similar to the unqualified T-50 coatings systems and are accounted for as such.

Approximately 75 percent of the T-50 coating systems in Unit 1 contain an organic zinc rich epoxy primer of Triangle H-197, an intermediate alkyd coating of Triangle T-50, and a phenolic epoxy topcoat of Phenoline 305; with average applied thicknesses of 3, 3, and 6 mils, respectively. The other T-50 coating systems in Unit 1 vary, with approximately 10 percent being a primer of Triangle T-50 and a topcoat of Phenoline 305.

For Unit 2, the majority of the T-50 coating systems (approximately 60 percent) use an IOZ primer (including Ameron Dimetcote 6, Mobil MZ-7, and Porter Zinc Lock 311), an intermediate coating of Triangle T-50, and a topcoat of Phenoline 305, with an average applied thickness of 3, 3, and 6 mils, respectively. Approximately 15 percent of the T-50 coating systems are a T-50 and Phenoline 305 system; and approximately 20 percent are a CZ-11/Triangle T-50/Phenoline 305 system.

From the, "Report on Evaluation of DBA Test Results for Unqualified Coating Systems that Include Triangle T-50 Alkyd Paint Located Inside Primary Containment at Diablo Canyon Power Plant," by KTA-Tator, Inc., all of the T-50 coating systems are expected to fail at the T-50 interface with a substrate or primer, leaving any primer intact. In 1988 the IOZ/T-50/305 and T-50/305 coatings systems were LOCA/DBA tested per the requirements of ASTM D3911-80. Both systems failed the test. Delamination and blistering are the failure mechanisms with delamination of 95 to 100 percent for the majority of the Triangle systems. Although not LOCA/DBA tested, due to similar failure mechanisms, the KTA-Tator report states that the OZ/T-50/305 system would fail in a similar manner as the T-50/305 system. Based on the test data and the KTA-Tator report, all of the T-50 coatings are shown to fail as chips and not as fine particulate. The T-50 and Phenoline 305 will delaminate from the substrate or primer and fail as chips, with a thickness equal to the sum of the T-50 and Phenoline 305 thicknesses. An average T-50 thickness of 3 mils and an average Phenoline 305 thickness of 6 mils, for a total of 9 mils, is assumed.

As discussed in the KTA-TATOR report referenced above, the chips should be a minimum of 1 to 2-inches square, and more likely larger than that based on the size of the chips that disbonded during the DBA test. For debris transport (debris interceptor) and strainer head loss testing, a conservative chip size distribution ranging in size from 1/2 inch x 1/2 inch to 1/8 inch x 1/8 inch was used. See Sections 3.e, Debris Transport, and 3.f, Head Loss and Vortexing, for additional information.

Calculations quantify the total quantities of 48,300 ft² and 49,200 ft² of unqualified coatings and degraded qualified coatings in Units 1 and 2, respectively, with an analysis maximum of 51,800 ft². Density information was not readily available for Triangle T-50 alkyd coating. The Guidance Report in NEI 04-07 gives a density value of 98 lbm/ft³ for typical alkyd coating systems. Lacking specific density data, a density of 105 lbm/ft³ for Phenoline 305 epoxy coating is conservatively assumed.

In addition to the T-50 coating systems and degraded qualified coating systems, there exists 500 ft² of original equipment manufacturer (OEM) coatings (with an assumed thickness of 6 mils) and 2267 ft² of structures/components with only a zinc primer. This 2267 ft² consists of 1267 ft² of galvanized weld repair coating approximately 2 mils thick, and the remaining 1000 ft² is un-top coated zinc primer with a thickness conservatively assumed to be 6 mils. These coatings are part of the 51,800 ft² inventory of unqualified coatings, and are assumed to conservatively fail as chips when performing strainer head loss testing activities. For testing of head loss across the fuel bottom nozzle, these coatings are conservatively assumed to fail as 10 micron particulate (and a typical density for inorganic zinc of 223 lbm/ft³ is used). Including the two different coating failure mechanisms is necessary to ensure conservative head loss test results. Coating chip debris is most conservative for strainer head loss testing (it reduces 'clean' screen area) and particulate coating debris is most conservative for fuel bottom nozzle head loss testing (because particulates bypass the strainer and accumulate at the fuel). DCPP does not take the results of EPRI 1011753 study into account in our OEM coating calculation. The approximate quantity of each coating type in Unit 1 and Unit 2 containments is listed below:

	Substrate	Coating Types	Total Area sq. ft.	Dry Film Thickness, mils
Unit 1				
Qualified	Steel	IOZ/Epoxy	280K	3/6
		Epoxy	3K	6
	Concrete	Epoxy	93K	3
Unqualified	Steel	OZ/Alkyd/Epoxy	22K	3/3/6
		IOZ/Alkyd/Epoxy	2K	3/3/6
		Alkyd/Epoxy	5K	3/6
		IOZ	4K	3
		Others[1]	17K	N/A
	Concrete	N/A	N/A	N/A
Unit 2				
Qualified	Steel	IOZ/Epoxy	281K	3/6
		Epoxy	2K	6
	Concrete	Epoxy	93K	3
Unqualified	Steel	OZ/Alkyd/Epoxy	1K	3/3/6
		IOZ/Alkyd/Epoxy	28K	3/3/6
		Alkyd/Epoxy	5K	3/6
		IOZ	4K	3
		Others[1]	12K	N/A
	Concrete	N/A	N/A	N/A

1. Other unqualified coatings include non-T50 unqualified coating systems, OEM, degraded qualified coatings, and margin.

Additionally, there is an unqualified high heat aluminum coating on the pressurizer. This coating, which is under the RMI insulation, is a silicon based coating with a thickness in the range of 2 mils, and a density in the range of 90 to 100 lbs/ft3 (100 lbs/ft3 is used for conservatism). The surface area of the coating that is destroyed is taken to be the surface area of the RMI which is destroyed on the pressurizer. This coating is taken to fail as 10 micron particulate for fuel bottom nozzle testing and as chips for strainer head loss testing. PG&E performed testing of the debris interceptors installed on all of the three crane wall doors and has determined that the debris interceptors are effective in capturing 65 percent of the 9-mil coating chips and 22 percent of the 2-mil coating chips (reference Section 3.e, Debris Transport).

For testing purposes, all the coatings in the ZOI of the LOCA are assumed to arrive at the sump in the form of particulate with a particle size of 10 microns. Sil-Co-Sil sand was selected as a surrogate for all coatings in the zone of influence of the LOCA based upon its size. The use of Sil-Co-Sil sand as surrogate for this purpose has been accepted by the NRC for other licensees. During the head loss test, agitation was introduced to prevent the settlement of the ground silica powder. See Section 3.f, Head Loss and Vortexing, for additional details.

For unqualified coating which fails outside the ZOI, paint chips were fabricated by the application of the specified coating system at the correct thickness on plastic sheets. The paint was then removed from the plastic sheets and sized appropriately (from 1/2 inch x 1/2 inch to 1/8 inch x 1/8 inch). The paint was applied using the existing painting procedures and using similar coatings of similar densities. During the head loss test, agitation was introduced to prevent the settlement of the unqualified coating paint chips.

- *Describe any ongoing containment coating condition assessment program.*

A controlled program for painting and special coatings has been in effect since the start of painting activities at DCPP in 1972. This program was done in accordance with the guidance on ANSI N101.2 and ANSI N5.12. Prior to March 1985, the coatings inside containment were applied per PG&E Specifications 8848 and 8831R.

Based on Allegation 100 (NRC SSER-21, September 1984), there was a concern regarding the coatings work inside containment may have a potential impact on performance of safety systems. In March of 1985, Specification 8875 was issued to address new coatings applied inside containment. New coatings used in containment will be Service Level 1 coatings, and applied in accordance with our Quality Assurance program. Based on this review of existing coatings in containment, PG&E Letter DCL-85-058, dated February 9, 1985, was sent to the NRC. This letter summarized PG&E's review, testing, and analysis of the coating condition in the DCPP containments and formally created a Coatings Monitoring Program.

The Coating Quality Monitoring Program is committed to meet the intent of a quality assurance program for containment coatings per 10 CFR 50 Appendix B. DCPP is committed to perform a monitoring program inspection during each refueling outage. The inspections are intended to provide assurance that the previously applied coatings, which did not have Q requirements, are performing satisfactory. This commitment is summarized in PG&E Letters DCL-85-058, dated February 9, 1985, and DCL-85-108, dated March 13, 1985, which were sent to the NRC. The monitoring program covers general inspections of coatings inside containment and specific inspection and testing of previously applied unqualified coatings.

The Coating Quality Monitoring Program is performed in accordance with two DCPP procedures. MIP CT-1.0 is the Containment Field coatings procedure which provides the methods, requirements, and responsibilities for Service Level 1 coatings work inside containment and for items designated for installation inside containment. MIP CT-2.0 is the Coating Quality Monitoring Program procedure which describes the coating quality monitoring program and its implementation in order to provide assurance of continued acceptable performance of coatings inside containment. MIP CT-2.0 describes the qualifications and training requirements for coating inspectors and applicators. Both procedures refer to the Specification 8875, which is the containment coating specification. Specification 8875 incorporates the ANSI N 101.2 as a basis for comparison and selection of coating systems for Service Level 1 coating.

At DCPP, the coating monitoring program inspections have always been done by a Level III inspector. The Level III inspectors are qualified by the criteria set out in MIP CT-2.0 and TQ1.NQ5, "Qualification and Certification of Quality Control Inspectors," and are also involved in coating industry organizations, like EPRI, SSPC, and the ASTM governing board concerned with Service Level 1 coatings. DCPP has also been participating with EPRI on the discussion with the NRC concerning the issue of "Aging and Degradation Survey for Nuclear Service Level 1 Coatings."

During each refueling outage, a thorough visual inspection is performed by a Level III inspector. These inspections are performed in accordance with recurring task work orders. At the beginning of every outage, this visual inspection is conducted on all accessible coated surfaces of the containment. This should be performed as soon as practical in the beginning of the outage and again prior to Mode 4. Included areas for inspection are components to be inspected internally, like the iodine removal unit housing, containment fan cooler unit (CFCU) fan housing, and CFCU coil housing.

During the inspection, if any degraded conditions are found, they are documented in the corrective action program. The condition is evaluated and a determination is made whether or not the repair work will be during the outage in which the condition was found. If the work is not completed during the current outage, then the degradation is documented as unqualified coating, to be repaired at a later date. After each outage the unqualified coatings are tracked in Calculations N-216 for Unit 1, and N-217 for Unit 2.

3i. Debris Source Term

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

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

> *<u>GL 2004-02 Requested Information Item 2(f)</u>*
> *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, "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:

- *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.*
- *A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment.*
- *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.*
- *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.

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

PG&E Response:

- *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.*

The compensatory measures, as stated in PG&E Letter DCL-03-097, dated August 8, 2003, Response to NRC Bulletin 2003-01, regarding containment housekeeping programmatic controls will remain in-place and are credited to control the latent debris burden. These measures include an aggressive ongoing containment cleaning program. This program has evolved over several years, and includes the following elements:

- General Employee Training has been augmented to include a segment on the importance of maintaining the containments free of debris;
- Routine work orders for cleaning containment prior to Mode 4 have been revised to include a detailed list of areas for cleaning and inspection;
- Containment cleanup activities and inspections are now scheduled later in the outage. Containment inspections are performed by management personnel, radiation protection personnel, a senior licensed operator, and personnel knowledgeable of the containment environment. These improvements allow the efficient use of manpower, and assure that the containment is cleaned prior to entering Mode 4;
- A containment cleanliness program has been established, and a program owner has been assigned. The program owner has the overall responsibility for containment cleanliness, and establishes procedures and necessary work orders to maintain clean containments; and
- Aggressive containment cleanup activities have been implemented to remove dirt and dust, including vacuuming of accessible cable trays and other accessible surfaces.

In addition to these measures, a recurring work order has been created for both units to perform a latent debris survey every other outage and/or after any invasive or extended maintenance (e.g., SG replacement). The latent debris survey will be performed during the upcoming 2R14 and 1R15 SG replacement outages. If the results of latent debris survey indicate the amount of the current latent debris load is greater than assumed in the analysis, corrective actions will be implemented to reduce the latent debris load. Based upon acceptable results of subsequent latent debris surveys utilizing the current containment cleaning procedures, visual inspection of containment cleanliness may be used in future outages in lieu of performing latent debris surveys.

- *A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment.*

Material exclusion procedures exist to verify that no loose debris is left following any activity performed in containment once containment integrity has been established. STP M-45B, "Containment Inspection When Containment Integrity is Established," is implemented for at-power entries, requires that a visual inspection be performed, and any debris found during the inspection be removed from containment. This procedure also requires that all tools, equipment, and material used in a work activity be removed from containment.

- *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.*

To maintain the required configuration of the containment recirculation function that supports the inputs and assumptions utilized to perform the mechanistic evaluation of this function, DCPP has implemented programmatic and process controls as described below.

Plant procedures, programs, and design requirements were reviewed to determine those that could impact the analyzed containment or recirculation function configuration. These reviews resulted in the identification of those documents that required revision or development of new documents to ensure maintenance of the inputs and assumptions into the future.

The engineering related documents that were revised or developed to support and maintain the required configuration control for maintenance of the inputs and assumptions that support the GSI-191 issue resolution are:

- Design Control and Design Change Reference procedures to provide for detailed analysis and evaluation of temporary or permanent modifications to SSCs inside containment, or in the required downstream recirculation flowpaths, to ensure the inputs and assumptions that support the GSI-191 issue resolution will be maintained into the future. This includes maintenance of debris source term considerations and component configurations in the flowpaths that support the recirculation function.
- Containment coatings inspection and evaluation procedures are in place to ensure:
    - The inspection procedure provides direction that each location of degraded or questionable condition of qualified or nonqualified coatings be promptly entered into the corrective action program.
    - Engineering evaluations are performed for each coating discrepancy to establish the extent of condition of the identified failure, and the probable cause for the failure. Engineering determines the additional evaluations that may be necessary to fully bound the extent of condition of each coating discrepancy, including, as appropriate, performance of expanded visual coatings inspections and performance of pull tests or cross-hatch tests.
    - Personnel performing initial coating visual inspections or extent-of-condition visual inspections are qualified to the applicable ANSI requirements.
    - Identified degraded or questionable coatings are remediated prior to plant heat-up following a refueling or maintenance outage. This remediation may include recoating the affected area with a qualified coating system, or removal of the degraded or questionable condition coatings to a sound and tightly adhered area.
- An insulation database has been established to ensure that maintenance activities do not change the analysis and modification input assumptions without an appropriate engineering evaluation.

- The inputs and assumptions for debris generation, debris transport, head loss determination (including chemical effects considerations), upstream, and downstream effects analyses, and associated testing have been documented in an approved engineering document (subject to the requirements of 10CFR50 Appendix B) to facilitate evaluation of conditions that may be contrary to analysis and modification input assumptions, and to ensure that future changes to the plant can be readily evaluated against these design and licensing basis criteria.

The plant documents that were revised or developed to support and maintain the required configuration control for maintenance of the inputs and assumptions that support the GSI-191 issue resolution are:

- Maintenance planning and work control procedures and processes were revised to ensure:
  - Links to design requirements were established to provide the job planners with the tools necessary to correctly plan work activities associated with containment, ECCS, and CSS.
  - The requirements for performing work in containment while the unit is operating were expanded to include additional requirements associated with protection of the recirculation function including provisions for obtaining engineering evaluations for complex evolutions.
  - Links to containment inspection requirements are included in job planner's guides to ensure the necessary information is provided in the work packages for implementation in the field.
- Containment access, inspection and surveillance procedures and processes were revised to ensure:
  - Procedures for containment access and containment closeout contain the necessary controls to ensure that containment will remain in a configuration that fully supports the inputs and assumptions associated with the resolution of GSI-191.
  - Procedures for containment inspections contain the necessary attributes to ensure the inputs and assumptions associated with analyses described previously are maintained. This includes attributes such as coatings, insulation, and latent debris.
- Procedures are in place to provide guidelines for cleaning of containment during refueling and maintenance outages. These procedures help ensure the attributes associated with the containment inspection and closeout procedures will be met.

A list of those documents that were revised or developed is provided below.

- CF3.ID9, “Design Change Development”
- MIP C-4.0, “Thermal Insulation”
- STP M-45A, “Containment Inspection Prior to Establishing Containment Integrity”
- STP M-45B, “Containment Inspection When Containment Integrity Is Established”
- STP M-45C, “Outage Management Containment Inspection”
- AD7.DC8, “Work Control”
- AD4.ID9, “Containment Housekeeping and Material Controls”

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

- *A description of how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65.*

Procedures are in place to evaluate maintenance activities and temporary changes that have the potential to affect the recirculation function.

Procedure STP M-45B (both units) verifies that no loose debris is left by an activity performed in containment during Modes 1 through 4, and this procedure provides limitations on the amount of hours personnel in containment may be below the 117 ft elevation outside the crane wall or below the RCP platforms inside the crane wall in Modes 1 through 4. The time restrictions are based upon the risk significance of personnel in containment causing recirculation sump obstruction as a result of an accident.

Procedure CF4.ID7, "Temporary Modifications," establishes the program for controlling temporary modifications that affect inservice plant structures, systems or components (SSC). This procedure requires that the temporary modification be evaluated for applicable design change evaluations sections of procedure CF3.ID9, "Design Change Development." Recirculation strainer function is a specific concern that is required to be addressed for all modifications inside containment.

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.

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

The following list summarizes the DCPP debris source term refinements:

- Removal of fire stops located inside the crane wall.
- Erosion testing of uncovered fire stops and unjacketed insulation outside the crane wall. The erosion test results are presented in the following table:

Material/Item	Erosion Value*
Unjacketed Temp-Mat	0.625%
Unjacketed Cerablanket	3%
Kaowool in Horizontal Fire Stops (with fire stop cover)	5%
Kaowool in Horizontal Fire Stops (without fire stop cover)	13%
Kaowool in Vertical Fire Stops	37%

*DCPP fire stop insulation erosion testing was performed at the Alion Science and Technology testing facilities in Warrenville, Illinois.

- Replacement of Temp-Mat inside the crane wall and pressurizer cubicle with stainless steel encapsulated Temp-Mat.
- Installation of additional stainless steel banding on calcium silicate insulated piping inside the crane wall.
- Installation of debris interceptors in the crane wall doors to stop debris which transports by tumbling along the floor, and to minimize suspended coating chips.
- Modification of the reactor cavity door to facilitate the transport of debris to the reactor cavity during pool fill-up.

- *Actions taken to modify or improve the containment coatings program*

No modifications or improvements were made to the current program.

3j. Screen Modification Package

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

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

PG&E Response:

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

A new containment recirculation sump strainer assembly was installed in Unit 1 during 1R14, and in Unit 2 during 2R14. The design modifications for Unit 1 and Unit 2 are similar. The strainer modification is one of the hardware changes required to bring DCPP into full compliance with NRC GSI-191 and GL 2004-02.

The strainer assembly includes front and rear strainers and plenums and is located in the containment annulus, outside of the crane wall. The front strainer is located at the 91 ft elevation of the containment building. The rear strainer is anchored at the 88 ft elevation. The front and rear plenums are connected at the entry of the two 14-inch RHR sump suction lines. The strainer assembly is designed to be submerged.

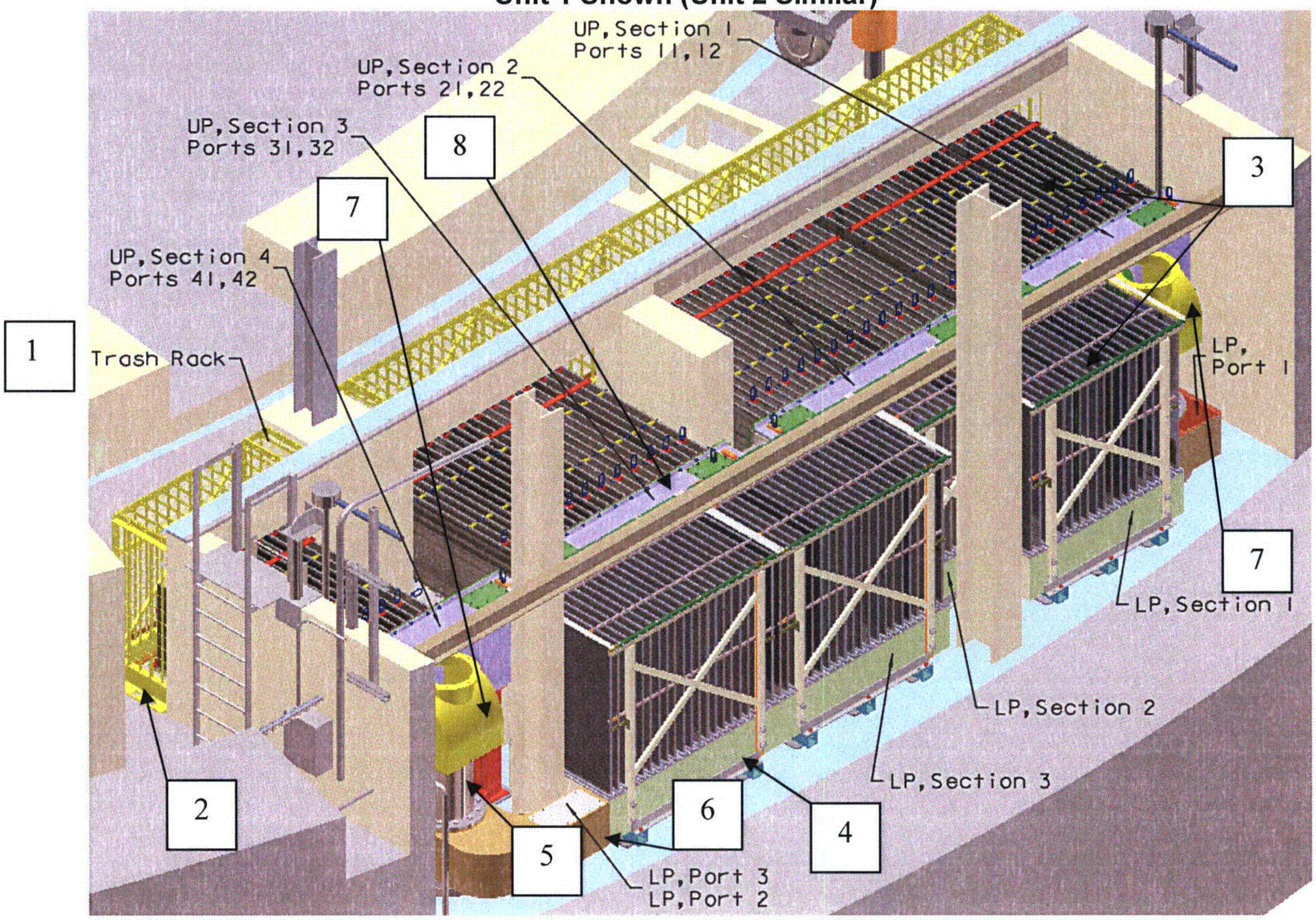
To prevent large debris from entering the sump, a trash rack (Figure 1, Item 1) with integral debris curb (Figure 1, Item 2) is included in the design. The trash rack openings are approximately 4 inches x 4 inches, and the debris curb is approximately 6-inches high. The trash rack assembly includes multiple modules which may be removed to widen the walkway path during refueling outages, if necessary.

The design includes a passive, safety-related strainer assembly custom-engineered by General Electric. The strainer assembly consists of vertically oriented perforated plates (Figure 1, Item 3), water collection plenums (Figure 1, Items 4 and 8), plenum downcomer straightening vanes (Figure 1, Item 7), vortex suppressors (Figure 1, Item 5), plenum pump-out drain lines plenum inspection access hatches, and expansion bellows (Figure 1, Item 6).

The perforated plate has holes of 3/32-inches diameter with a wire cloth overlay. The General Electric design is intended to mitigate the potential for "thin bed" effect and associated head loss across the "thin bed." The total perforated plate effective surface area is 3276.5 square feet. For two pump operation, the approach velocity would be approximately 0.00552 feet per second. Tested plenum downcomer straightening vanes and cruciform-shaped vortex suppressors minimize any vortexing. Two expansion bellows were included in the design to relieve structural stresses associated with thermal expansion. The strainer assembly includes common plenums that form suction chambers for the two RHR pump suction lines.

Stainless steel materials were used in the construction of the trash racks and strainer assemblies.

Figure 1: Containment Recirculation Sump Passive Strainer Assembly
Unit 1 Shown (Unit 2 Similar)



- *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.*

Other changes associated with the modification included relocating and/or reconfiguring existing components to remove interferences associated with the strainer installation. Modifications included:

- Unit 1 and Unit 2: Rerouting of the 2-inch drain line of the containment fan cooling units to the front of the sump and relocation of associated supports.
- Unit 1 and Unit 2: Relocation of RHR sump level elements and associated supports within the sump.
- Unit 2: Removal of a column brace from the sump and installation of a column brace outside the sump to provide an equivalent function.
- Unit 2: Sump grating above the screen and ladder modifications.

There were no additions of whip restraints or missile shields since the strainer is located outside the crane wall and is not subject to pipe whips, jet impingement, or missile impact.

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).

> *GL 2004-02 Requested Information Item 2(d)(vii)*
> *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.*

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

PG&E Response:

The replacement strainer is comprised of three assemblies:

- Trash rack assembly
- Front strainer assembly
- Rear strainer assembly

Refer to Section 3.j, Screen Modification Package, Figure 1, for composite design of the strainer.

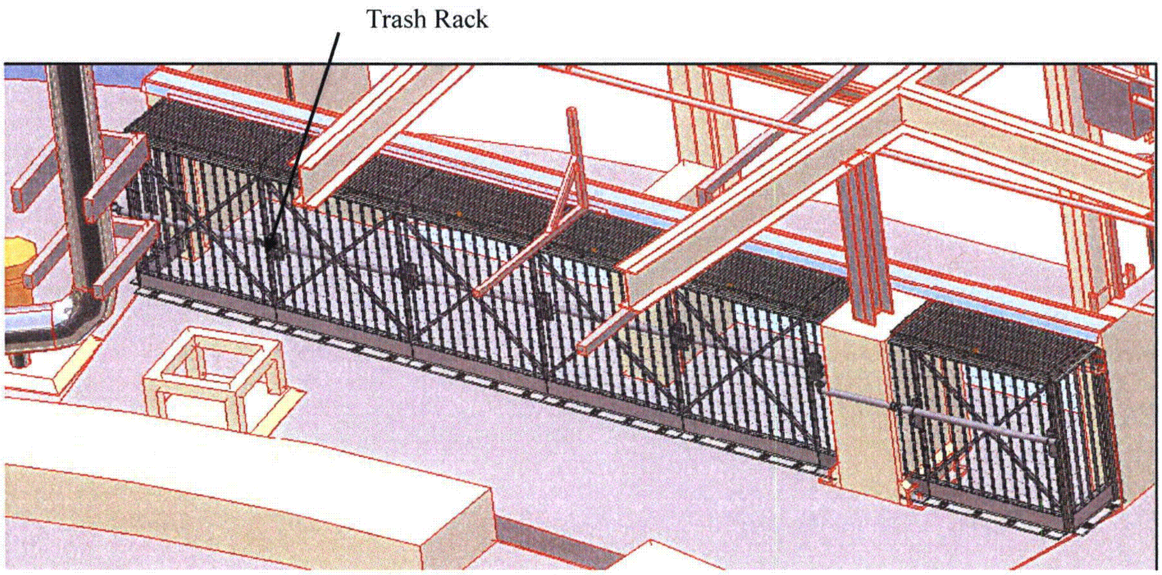
The entire strainer assembly is located inside the containment structure in the RHR recirculation sump area. This area is inside the annulus area of Containment, the area formed by the crane wall and the containment exterior wall. This area is bordered by approximately 9 feet long concrete side walls on 2 sides and the containment exterior wall on one side. There are two floor elevations inside this area: 91 ft (floor elevation), and 88 ft (elevation of the RHR suction lines). The trash rack and front strainer assembly are located at the 91 ft elevation and the rear strainer assembly is located at the 88 ft elevation. The location of the strainer assembly is such that it is not subject to loading from pipe whip, jet impingement, or missile impact.

The trash rack and strainer assemblies are stainless steel, providing an equal rate of thermal expansion. Provisions are included in the equipment design to accommodate thermal growth relative to the concrete support interface.

Trash Rack Description

The trash rack assembly is a modular design. Each module consists of front and top panels: the front panel consists of a plate with cut windows reinforced by a cross bar, and the top panel is a welded structure consisting of structural bars and flat bars. The trash rack is an enclosed structure since all modules are bolted together, and both sides of the trash rack are covered by side panels. The top and bottom of the front panels are bolted to a steel beam that is connected to the sump structure concrete baffle walls and the containment structure 91 ft elevation floor slab, respectively. The side panels are bolted to the sump structure concrete baffle walls. Refer to Figure 1 for this assembly.

Figure 1: Front Trash Rack Assembly



Front Strainer Description

The front strainer assembly consists of a series of vertical strainer disks with a collection plenum, discharging strained water to the RHR pump inlet piping via the front strainer plenum. See Figure 2 for details. The front strainer assembly has four modules of similar design but of different widths to accommodate obstructions within the sump area. Each module has a series of vertical plates (also referred to as disks), which are bolted to the front plenum. The strainer disks are composed of perforated plates with 3/32-inch diameter holes on a triangular pitch. The vertical strainer plates are configured in sandwich sections that filter the flow on both sides of the plates, and then direct the filtered fluid into the front plenum.

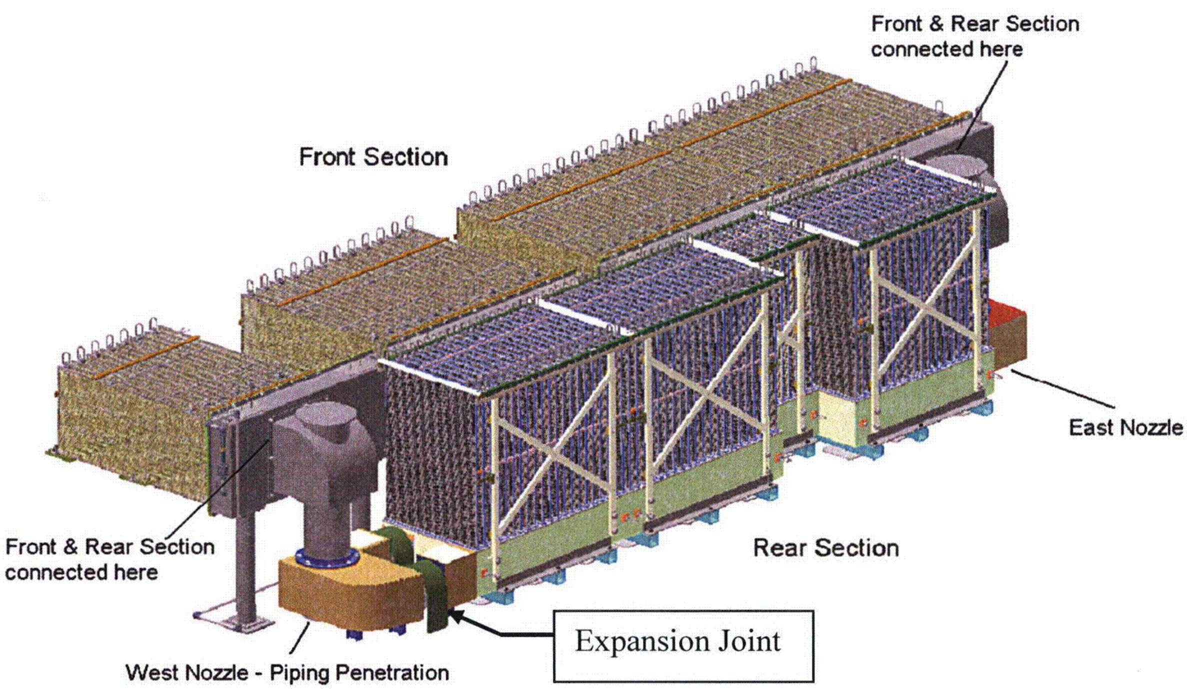
Several columns, braces, and horizontal cross bars are attached to the rear section of the front strainer assembly to stabilize the structure for lateral loading conditions. The strainer assembly is attached to baseplate assemblies that are comprised of both bolted connections (expansion anchored to ground) and slotted-bolted connections (connected to the plenum) to allow for thermal expansion.

Rear Strainer Description[1]

The rear strainer (see Figure 2) consists of a series of vertical strainer plates mounted on top of the rear plenum. Similar to the front strainer configuration, the vertical strainer plates are composed of perforated plates and are configured in sandwich sections that filter the flow and then direct the filtered fluid into the rear plenum.

The rear strainer assembly consists of four modules of similar design but different widths to accommodate obstructions within the sump pit. The four modules are continuously connected between the East and West RHR inlet nozzles, and fixed at the East end. An expansion joint is installed at the end of the fourth module to allow for thermal expansion at the West end of the rear strainer assembly.

Figure 2: Front and Rear Strainer Assembly



- *Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.*
- *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.*
- *Summarize the evaluations performed for dynamic effects such as pipe whip and jet impingement associated with high energy line breaks (as applicable).*

Separate finite element models were developed for the analysis of the trash rack, front strainer assembly, and rear strainer assembly. These finite element models were based on an ANSYS

[1] This description is for Unit 1; Unit 2 is similar.

finite element analysis program. Each model was developed with the proper boundary conditions and analyzed for various loading conditions. Bolted connections are modeled as three way translational supports wherever applicable. The boundary conditions also consider slotted joints by releasing the appropriate degree of freedom. The finite element analyses were supplemented by manual hand calculations of welds, fasteners, and anchorage.

The 3D Solid finite element models of the front and rear strainer assemblies were developed with the perforated plates modeled as equivalent solid plates. These plates were then modified in the model to adjust for the perforations by modifying material properties. The model does not include bolts and fasteners as separate parts. However, forces and moments are extracted from the model as interface loads and are applied in the manual calculations where fasteners are evaluated.

The following loads and load combinations are applicable to the evaluation of all three strainer assemblies.

- D Dead load of structure and equipment loads –see note 1.
- DW Dead load of structure and equipment including debris weight and hydrodynamic mass (in water) – see note 1.
- L Live load - see note 2.
- To Thermal loads - see note 3.
- DE Loads resulting from the Design Earthquake.
- CP Accident pressure load due to LOCA or high energy line break (HELB) - see note 4.
- R,J Pipe Restraint and pipe whip reactions and jet impingement loads due to LOCA or HELB – see note 5.
- DDE Load resulting from the Double Design Earthquake.
- HE Load resulting from the Hosgri Earthquake.
- LTSP Load resulting from the Long Term Seismic Program Earthquake.
- M Missile load – see note 5.
- S Stress Allowable.

Notes:

1. The strainer analysis was performed using weights of approximately 30 percent above calculated values.
2. Live load includes hydrostatic forces acting on a fully clogged strainer either partially or fully-submerged in the design water level inside the containment structure (crush pressure).
3. A thermal case with ΔT equal to 192°F was evaluated in the analysis based on a maximum water temperature of 262°F and a stress-free temperature of 70°F.
4. Accident pressure load is not applicable to the strainer system, since it is an open system.
5. The strainer location is such that pipe restraint/whip reactions, jet impingement loads, and missile impact loads are not applicable.

Load Condition	Load Combination
Operating condition	D + L + To + DE
Accident 1	DW + L + DDE + CP + R + J + M
Accident 2	DW + L + HE + CP + R + J + M
Accident 3	DW + L + LTSP + CP + R + J + M

Also, both the response spectrum analysis method and the equivalent static analysis method were used to analyze the various portions of the strainer system.

When response spectrum analysis was used, the modal analysis results were combined using the square root of the sum of the square method. This analysis includes consideration for missing mass.

When the equivalent static method was used, a 3D absolute sum method was used to combine the results, conservatively assuming that the entire mass of the structure participates in the first mode. Additionally, all equivalent static results were scaled up with a static coefficient factor.

Maximum stresses in each of the strainer components were computed using the ANSYS postprocessor and compared with the applicable ASME code allowable stress limits to calculate the stress ratios. For the worst case accident, Case 3 (as defined above), resultant stresses were compared to Level D allowables.

In order to evaluate the anchorage to concrete, the interface loads were obtained from the finite element analysis with the worst-case combined loading.

Structural Analysis of the Trash Rack Assembly

The front trash rack assembly has six sections. The finite element model represents one typical module, modeled as a 3D solid finite element (see Figure 4). The trash rack was analyzed and determined to be a rigid structure, therefore, the equivalent static method was used for analysis. A conservative seismic acceleration value was used for both the horizontal and vertical analyses.

The trash rack model includes deadweight, tributary weight of the 2-inch containment fan cooler drain pipe, live loads (40 pounds per square foot), and seismic loading. The trash rack is an open system, therefore, hydrodynamic mass is negligible. As a bolted structure, the trash rack is designed to accommodate thermal expansion. Temperature induced stresses on the trash rack are negligible, however, thermal growth was considered in determination of the required gap between the adjacent structural column and the trash rack modules. Overall stresses in the trash rack structure were found to be very low.

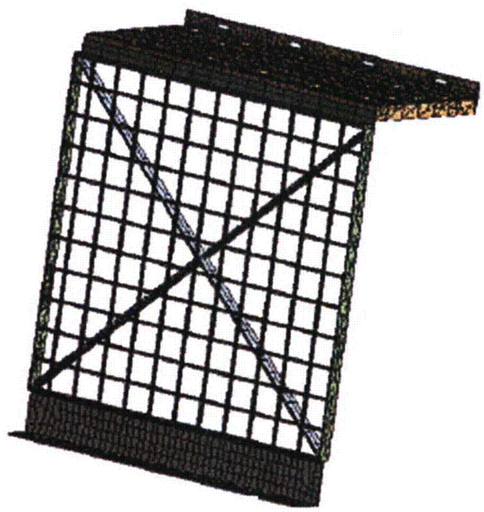
Trash Rack Results Summary

Condition	Max stress intensity (ksi)*	Stress Limit (ksi)	Stress Margin**
Operating condition	9.34	28.1	3.0
Accident 3	10.2	40.9	3.94

* Max stress values including peak stresses resulting from singularities

** Stress Margin = (Stress Limit/Max stress intensity)

Figure 4: Finite Element Representation of an Open-End Module



Structural Analysis of the Front Strainer Assembly

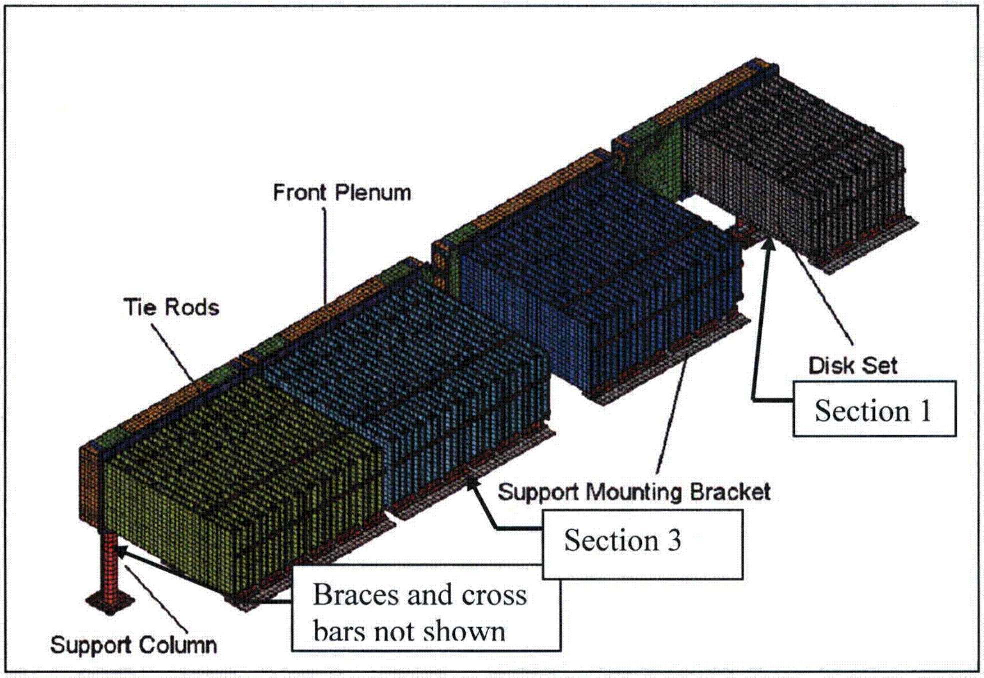
The finite element model of the front strainer assembly includes Sections 1 and 3 as shown in Figure 5. It was not necessary to model the entire front strainer since the structure is composed of a series of modules with similar geometry, and each module is connected by sliding joints between the plenum sections. Therefore, two representative sections were modeled and analyzed. Appropriate boundary conditions were applied to model the baseplate and anchor bolt attachments at the floor elevation. The aforementioned sliding joints in the plenum between the different modules were modeled by releasing the appropriate degree of freedom.

For the front strainer component stress analysis, a 3D square root sum of the squares method was used, considering the response spectra analysis. An equivalent static acceleration, 3D Absolute Sum, method was conservatively used for bolting, weldment, and anchorage evaluations.

The resultant stresses were evaluated to meet the requirements of ASME code Section III, Subsection NC, ND, NF, NG, and Appendix F. Stress margins for various components were calculated for the operating condition and various accident conditions. The stress margins for key components are listed below for Case 3 with faulted allowables.

Component	Case 3 Stress Margin
Front Section Frame and Fingers	1.67
Front Section Perforated Plates (Disk)	1.82
Front Section Tie Rods	5.27
Front Section Plenum	1.18
Front Section Anchor Bolts	1.08

Figure 5: Finite Element Model of Front Strainer Assembly



Structural Analysis of the Rear Strainer Assembly

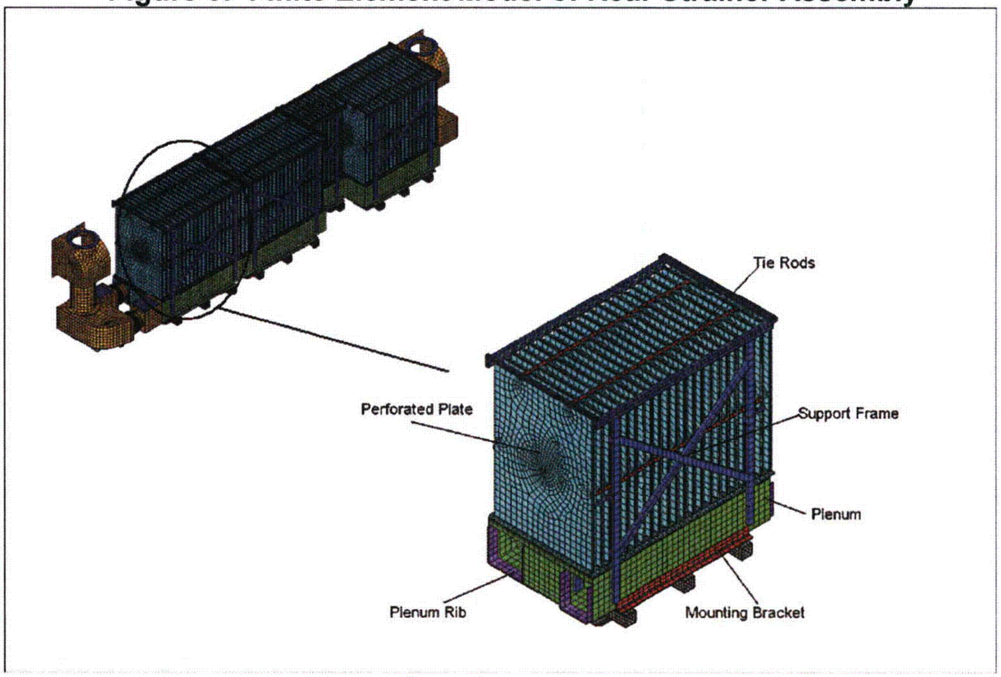
The finite element model of the rear strainer includes the entire rear strainer assembly. The model includes key components such as the RHR piping inlets, the expansion joint at the West end, the bottom plenum, and the vertical disks. For the rear strainer, all analyses (including component stress, bolting, weldment, and anchorage) were performed using the equivalent static acceleration method with a 3D Absolute Sum combination for spatial considerations.

The lower plenum is joined together as a single unit, with thermal growth occurring from East to West. The expansion joint allows for thermal expansion. The four baseplates and anchorage nearest to the fixed end of the rear plenum were analyzed for shear loading due to accident thermal expansion constraint. Thermal expansion was allowed at the other anchorage locations by the use of slotted connections, therefore, the appropriate degrees of freedom were released in the model.

The resultant stresses were evaluated to meet the requirements of ASME Code Section III, Subsection NC, ND, NF, NG, and Appendix F. Stress margins for various components were calculated for the operating condition and various accident conditions. The stress margins for key components are listed below for Case 3 with faulted allowables.

Component	Case 3 Stress Margin
Rear Section Frame and Fingers	1.59
Rear Section Perforated Plates (Disk)	1.45
Rear Section Tie Rods	1.25
Rear Section Plenum	1.04
Rear Section Anchor Bolts	1.03

Figure 6: Finite Element Model of Rear Strainer Assembly



In summary, the analysis results show that the trash rack, suction strainers, plenum assemblies, and various components including welds, fasteners, and supports meet the allowable stress limits of the ASME Boiler & Pressure Vessel Code, Section III, 1989 Edition, Subsections NC, ND, NF, NG, and Appendix F, as applicable. All anchor bolts were analyzed to meet the DCPP anchor bolting requirements and manufacturer recommended design, as applicable.

- *If a backflushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow.*

No credit is taken for a backflushing strategy.

Debris Interceptor Doors

The crane wall doors on the 91 ft elevation of containment were modified to perform the function of debris interceptors. The structural analysis of the debris interceptor doors includes analysis for seismic loading as well as hydrostatic and hydrodynamic loading caused by LOCA conditions. The debris interceptor doors are analyzed considering a fully clogged condition. The effects of sloshing inside containment, caused by a flooded condition excited by seismic accelerations, are included in the hydrostatic and hydrodynamic loads. The seismic analysis considers the effects of the worst case design basis earthquake, including the Long Term Seismic Program Earthquake. The doors, wall anchorages, and debris interceptor components are analyzed individually by classical methods. Acceptance criteria for the debris interceptor doors are in compliance and consistent with the design basis for safety related containment internal structures.

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.

Provide a summary of the upstream effects evaluation including the information requested in GL 2004-02 Requested Information Item 2(d)(iv).

> *GL 2004-02 Requested Information Item 2(d)(iv)*
> *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.*

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

PG&E Response:

As part of the sump inventory, debris generation, and debris transport analyses, an evaluation of flowpaths necessary to return water to the recirculation sump strainer was performed by Enercon Services Inc. and documented in WES007-PR-02, "Evaluation of Containment Recirculation Sump Upstream Effects for the Diablo Canyon Power Plant." This evaluation was performed in accordance with the recommendations contained within NEI 04-07 to identify those flowpaths that could result in the holdup of water not previously considered. These flowpaths included those areas into which CS and RCS break flow would enter. The flowpaths and holdup points were identified using information regarding DCPP safety features and accident analyses, as well as cross-sectional drawings used to identify major floor elevations and containment compartments. By examining each elevation in containment, Enercon was able to identify physical and structural features that would affect the flow of debris and water to lower containment. This evaluation identified architectural or equipment features to be considered with regard to calculating the minimum containment water level based on water retention and pinch points as well as considering possible plant modifications.

After holdup from the refueling cavity drain, ductwork, and holdup curbs had been conservatively estimated and the basis for no other significant sources of liquid holdup had been established, it was determined that all other water return flowpaths have sufficiently large openings to prevent the holdup of significant quantities of water that could challenge the containment minimum water level analysis. Therefore, the remaining water level is still sufficient to provide the containment minimum water level.

As part of the containment water level analysis WES007-PR-02, "Evaluation of Containment Recirculation Sump Upstream Effects for the Diablo Canyon Power Plant," holdup volumes were calculated for all spray return pathways that physical design features such as curbs, toe plates, or recessed areas (as explained above) would function to reduce the quantity of water available in the containment sump pool. The containment water level analysis was also compared against the debris generation and debris transport analyses to ensure that no new holdup volumes were created as a result of debris blockage of the required flowpaths.

The required flowpaths for return of water to the containment sump pool include the refueling canal drains, the stairwells connecting the various elevations of containment, and the openings (doorways) within the crane wall.

The refueling canal drain for both Units 1 and 2 is a single 8-inch drain pipe that is protected by a basket approximately 8 inches tall with openings of approximately 4 inches x 4 inches which are sufficiently large to prevent any credible debris that may be generated as a result of the break from blocking this flowpath. Therefore, there is no expected blockage of the refueling canal drain. The upper internals laydown area is within the refueling canal and this area is slightly recessed below the nominal refueling canal floor. This is an area of potential holdup of water and it has been estimated that this area could holdup approximately 244 ft^3. This volume is not credited in the minimum containment water level.

The three crane wall doors for Units 1 and 2 were modified to make them less susceptible to blockage due to the transport and accumulation of floating debris as part of DCPP's commitments to Bulletin 2003-01. The Unit 1 doors have been revised during 1R14 as part of the GL to change the doors to debris interceptors. The Unit 2 doors will be modified during 2R14.

As part of the physical modifications installed in the plant to resolve GSI-191, debris curbs and trash racks were installed as elements of the replacement strainer to limit the quantity of large debris that could interact with the recirculation sump strainer. The design of the debris curbs considered the potential for holding up, or choking, the necessary water flow to the sump strainer. The design ensured that even if fully blocked by large debris, sufficient flow area would be available over the top of the debris curbs to provide the required minimum water level and flow to the recirculation sump strainer.

As a result of the evaluations performed and physical changes completed, DCPP has determined that the upstream effects analysis provides the necessary level of assurance that the required volume of water will be available to the recirculation sump for the function to meet the applicable requirements as set forth in NEI 04-07 and GL 2004-02.

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.

> *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 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 sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.*
>
> *GL 2004-02 Requested Information Item 2(d)(vi)*
> *Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptable to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.*

- *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.*
- *Provide a summary and conclusions of downstream evaluations.*
- *Provide a summary of design or operational changes made as a result of downstream evaluations.*

PG&E Response:

The evaluations listed below were developed to address 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. Close-tolerance subcomponents in pumps, valves and other ECCS and CSS components were evaluated for potential plugging or excessive wear due to extended post-accident operation with debris-laden fluids. The evaluations were developed in accordance with WCAP-16406-P, Revision 1, and the accompanying NRC SE. No exceptions were taken to the WCAP-16406-P methodology.

- Evaluation of Containment Recirculation Sump Downstream Effects for Diablo Canyon Power Plant
- GSI-191 Downstream Effects for Diablo Canyon Debris Ingestion Evaluation
- Diablo Canyon Sump Debris Downstream Effects Evaluation (GSI-191): Erosive Wear on the ECCS and CSS Valves
- Diablo Canyon Downstream Sump Debris Effects Evaluation of Auxiliary Equipment
- ECCS Debris Ingestion Evaluation Mechanical Seal Disaster Bushing Wear and Resulting Outflow Leakage

"Evaluation of Containment Recirculation Sump Downstream Effects for Diablo Canyon Power Plant" evaluated the potential for blockage of the equipment in the ECCS and CSS recirculation flow paths. As part of the resolution for GSI-191, new ECCS screens were installed in DCPP Unit 1 and Unit 2 (see Section 3j). The new screens were specified to be fabricated from stainless steel plates with holes of 3/32-inch perforations. From the results of the evaluation, there are no blockage/plugging issues for existing piping, valves, instrumentation lines, orifices, eductors, heat exchanger tubes, and containment spray nozzles. Although the blockage evaluation was performed on the previous screen configuration with 1/8-inch round openings, the blockage evaluation was reviewed and determined to be conservative for the new replacement screen with nominal 3/32-inch round openings. A post installation inspection was performed on the replacement screens to verify that there were no gaps between the joints of any two adjacent surfaces greater than the nominal hole or gap size. The potential for blockage of the reactor vessel level instrumentation system (RVLIS) is not included in this evaluation. DCPP has a Westinghouse designed RVLIS for which WCAP-16406-P states there is no blockage concern due to the debris ingested through the sump screen during recirculation.

"GSI 191 Downstream Effects for Diablo Canyon Debris Ingestion Evaluation," determined the quantity and size of debris which may pass through the containment sump screens, and the concentration of this debris in the sump pool following a high energy line break for DCPP. Particulate debris sources with a characteristic size of at least 0.125-inch (approximately 33 percent larger than the replacement screen hole size of 3/32-inch) will not pass through the replacement sump screen, and are not considered in downstream analysis of valves and equipment.

The mass of debris in the recirculating fluid that passes through the sump is characterized in terms of parts per million (ppm). For downstream effects, the total initial debris concentration (MC) comprised of the individual debris concentrations is defined as the ratio of the solid mass of the debris in the pumped fluid to the total mass of water that is being recirculated by the ECCS and CSS: Fibrous concentration = 8.2 ppm, particulate concentration = 87.2 ppm; coatings concentration = 278.2 ppm; therefore, MC = 373.6 ppm

"Diablo Canyon Sump Debris Downstream Effects Evaluation (GSI-191): Erosive Wear on the ECCS and CSS Valves," documents the evaluation of the downstream effects of sump debris with respect to erosive wear on the valves in the ECCS and CSS at DCPP Units 1 and 2 using the WCAP-16406-P methodology.

A detailed erosive wear evaluation was required for 12 ECCS throttle valves, Valves 8822A-D, 8904A-D, and 8810A-D. Erosion of valves, calculated as a change in flow area divided by the original flow area ($\Delta A/A$), must remain less than 3 percent $\Delta A/A$. This criterion was established in WCAP-16406-P to prevent erosive wear from significantly impacting the flow rate through the valves. The results of this evaluation show that all valves pass the erosion evaluation using the depleting debris concentration evaluation.

Summary of Valve Erosion Results

Valve ID	ΔA/A (%)	Acceptable?
8822A-D	0.66	Yes
8904A-D	1.31	Yes
8810A-D	2.26	Yes

"Diablo Canyon Downstream Sump Debris Effects Evaluation of Auxiliary Equipment" addresses wear and abrasion from debris ingestion on the DCPP auxiliary equipment. This includes the effects of abrasive and erosive wear on ECCS and CSS pumps, heat exchangers, orifices, and spray nozzles following the methodology in WCAP-16406-P.

Erosion is defined as the gradual wearing away of material on an object due to particles impinging on the surface of the object. Abrasion is defined as the gradual wearing away of material on an object due to friction of particles rubbing the surface of the object.

For heat exchangers, orifices, and spray nozzles, the two concerns raised by debris ingestion are plugging (previously addressed) and failure due to erosive wear. Failure of the heat exchangers, orifices, and spray nozzles to maintain system performance could occur as a result of loss of wall material caused by erosive wear.

1. For heat exchangers, as long as the sum of the required wall thickness necessary to retain pressure and the wall thickness lost due to erosion is less than the actual wall thickness, failure will not occur.

2. For orifices, an increase in the system flow rate through the orifice of up to 3 percent is permissible without affecting the system performance and hence causing failure.

3. Spray nozzle function is maintained as long as the erosive wear results in less than a 10 percent flow increase.

The DCPP heat exchangers, orifices, and spray nozzles were evaluated for the effects of erosive wear for a constant debris concentration of 373.6 ppm over the mission time of 30 days. The erosive wear on these components was determined to be insufficient to affect the system performance.

For pumps, the concern raised by debris ingestion through the sump screen during recirculation is failure due to abrasive and erosive wear. Three aspects of pump operability are potentially affected by debris ingestion including hydraulic performance, mechanical shaft seal assembly performance, and mechanical performance (vibration) of the pump.

1. For hydraulic performance, as long as the increase in the wear ring gap due to the erosive wear of the sump debris does not affect the pump discharge flow, the pump will maintain positive flow margin, i.e., have sufficient flow to cool the core. From WCAP-16406-P, the wear ring gap may increase to double the design clearance without

affecting the hydraulic performance of the pump. Quadrupling the wear ring gap has an insignificant impact on the hydraulic performance of the pump.

2. For the mechanical shaft seal assembly performance, the concern is failure of the backup seal bushing due to wear from the sump debris. The majority of the plants reviewed in WCAP-16406-P have seal bushings made of carbon/graphite. WCAP-16406-P states that when the disaster bushing is of a carbon (graphite) material, the bushing will need to be replaced with a more wear resistant material, such as bronze. Alternatively, an evaluation of the reliability of the disaster bushing can be performed in cooperation with the pumps' mechanical seal supplier.

3. For multistage pumps, vibration may occur due to the increase in the wear ring gap. From WCAP-16406-P, for symmetric wear of JHF model pumps and RL-IJ model pumps, the wear ring gap may increase to 2.8 times the design clearance without adversely affecting the pump dynamic performance. For other models of multistage pumps, vibration is not a concern for symmetric wear increases of up to 2.0 times the wear ring gap design clearance.

   Experimental data described in WCAP-16406-P indicates a packing type wear on the discharge side wear rings, and a free flowing abrasive type wear on the suction side wear rings of multistage pumps. This difference in wear type results in asymmetric wear of the pump wear rings. Appendix R of WCAP-16406-P identifies the method by which the acceptable amounts of asymmetric wear for multistage pumps can be defined.

For the DCPP ECCS pumps, the effect of debris ingestion through the sump screen on three aspects of operability, including hydraulic performance, mechanical shaft seal assembly performance, and mechanical performance (vibration) of the pumps, were evaluated. The hydraulic and mechanical performances of the pumps were determined to not be affected by the recirculating sump debris for the 30-day mission time of the pumps.

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 ECCS pump primary (mechanical) seals are assumed to experience a single passive failure. There has been no demonstration that the ECCS pump primary seals would fail during a postulated LOCA. The 40-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 DCPP 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 single passive failure of the pressure boundary. Therefore, in accordance with the design for external recirculation loop leakage for ECCS components (FSARU Section 6.3.3.2.7), Summary Report, "ECCS Debris Ingestion Evaluation Mechanical Seal Disaster Bushing Wear and Resulting Outflow Leakage" documented the effect of debris ingestion on ECCS pump mechanical seal disaster bushings installed at DCPP after a postulated single passive failure of the primary seal.

The disaster bushings were evaluated with regard to sustaining sealing ability post LOCA. The evaluation estimated the increase in disaster bushing diametrical clearance as a result of debris ingestion, and the resulting maximum leakage as a result of enlarged clearances. An existing procedure was enhanced to address the potential of post-LOCA external recirculation loop leakage, and to provide the process to detect and isolate the leak. In support of this procedure, a new Operations procedure was created to provide the direction necessary to isolate one train of ECCS in the event a leak is detected during post-LOCA recirculation, and an existing annunciator response procedure was revised.

The downstream effects evaluations show that the DCPP ECCS and CSS equipment would not fail as a result of blockage, plugging, wear, or abrasion from the effects of debris ingested through the containment sump screen during recirculation mode of the ECCS and CSS.

In summary, no design modifications were required as result of the downstream effects evaluations. As noted above, there was a revision to existing procedures and the creation of a new procedure to provide the process to detect and isolate a leak during post-LOCA recirculation.

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.

- *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.*

PG&E Response:

The evaluations listed below were developed to address the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on core cooling.

- Diablo Canyon Units 1 and 2 GSI-191 Downstream Effects - Vessel Blockage Evaluation
- Assessment of Diablo Canyon GSI-191 Fuel Blockage Bottom Nozzle Tests
- LOCADM Analysis for Diablo Canyon Power Plants

"Diablo Canyon Units 1 and 2 GSI-191 Downstream Effects - Vessel Blockage Evaluation," determined the potential for reactor vessel blockage from debris carried downstream of the containment sump screen. In addition to locations at the core inlet and exit, other possible locations for blockage within the reactor vessel internals which might affect core cooling were assessed. The smallest clearance in the reactor vessel exclusive of the core was found to be 0.52 inches and 0.46 inches for DCPP Units 1 and 2, respectively. These dimensions are approximately five times greater than the dimension of the strainer holes in the containment sump screen.

Therefore, any debris that could make it through the 3/32-inch holes in the strainer would not challenge the limiting (smallest) clearances in the vessel.

"Assessment of Diablo Canyon GSI-191 Fuel Blockage Bottom Nozzle Tests" is an alternate assessment of fuel blockage performed for DCPP. DCPP is taking exception to the WCAP-16406-P screening evaluation method. A series of fuel assembly bottom nozzle head loss tests were performed by PG&E at the sump screen vendor test facility. The fuel bottom nozzle head loss effects were evaluated by Westinghouse through a comparison between the measured head loss of the test data and available driving head for the various DCPP LOCA scenarios.

The Westinghouse comparisons showed that sufficient driving head is available to match the head loss due to debris buildup, therefore, adequate flow will enter the core to match boil-off, and the core will remain covered. Because the core remains covered, Westinghouse concluded that no late heatup occurs, and the maximum local oxidation, the corewide oxidation, and the peak cladding temperature calculations for the traditional LOCA analyses are still considered applicable. (See Section 3.f, Head Loss and Vortexing, for details on the bottom nozzle head loss tests.)

"LOCADM Analysis for Diablo Canyon Power Plants" used the LOCADM code from WCAP-16793-NP, Revision 0, to predict the growth of fuel cladding deposits and to determine the clad/oxide interface temperature that results from coolant impurities entering the core following a LOCA.

The stated acceptance criterion is that the maximum cladding temperature maintained during periods when the core is covered will not exceed a core average clad temperature of 800°F. This acceptance basis is applied after the initial quench of the core and is consistent with the long-term core cooling requirements stated in 10 CFR 50.46 (b)(4) and 10 CFR 50.46 (b)(5).

An additional acceptance criterion is to demonstrate that the total debris deposition on the fuel rods (oxide plus crud plus precipitate) is less than 50 mils. This is based on the maximum acceptable deposition thickness before bridging of adjacent fuel rods by debris is predicted to occur. Debris accumulation in the fuel was observed at the lower grid locations during testing. The testing showed that the bridging that occurred at the grids was acceptable, and that flow through the accumulated debris bed was sufficient to ensure cooling of the fuel.

The evaluation was performed with the LOCADM code using DCPP specific data. The purpose of this evaluation was to use the LOCADM code to predict the growth of fuel cladding deposits and to determine the clad/oxide interface temperature that results from coolant impurities entering the core following a LOCA. The results of this evaluation are presented in the table below. These results show that the calculated fuel cladding deposits and clad/oxide interface temperature do not challenge the acceptance criteria.

Results of All Cases

Case	Scale Thickness (μm)	Total Deposition Thickness (μm)	Total Deposition Thickness (mils)	Max Clad Temperature (°F)
Maximum sump volume	17.05	309.05	12.17	413.8
Minimum sump volume	18.90	310.90	12.24	413.8
Minimum with 'Bump-up'	20.00	312.00	12.28	413.8

For the minimum sump water volume cases, LOCADM was also run with increased quantities of debris – in accordance with the bump-up factor methodology. The bump-up factor had a negligible effect on both the total thickness and fuel cladding temperature.

The results of these evaluations show that DCPP can maintain adequate long-term core cooling post-LOCA.

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.

- *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.*
- *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. ML0726007425).*

PG&E Response:

WCAP-16530-NP

Post-LOCA chemical precipitates in the recirculation pool were calculated using the methodology in WCAP-16530-NP, Rev. 0. PG&E has not credited any of the additional inputs to the WCAP-16530-NP model outlined in WCAP-16785-NP (silicate inhibition of aluminum corrosion, variance in corrosion rates of aluminum alloys, and aluminum solubility at elevated temperatures). Plant specific inputs to the WCAP-16530-NP methodology include the following:

- Post-LOCA containment recirculation pool temperature profile (from WCAP-14282, "Evaluation of Peak CCW Temperature Scenarios for DCPP Units 1 & 2"). The scenarios within WCAP-14282 attempt to maximize recirculation pool temperatures. Attachment 8 of Calculation M-1093 verifies adequate extraction of data from the WCAP-14282 Figure for input into the chemical effects spreadsheets.
- Post-LOCA containment atmosphere temperature profile (temperature profile from FSARU for aluminum/zinc corrosion was used). The WCAP-16530-NP model was developed using data that covered a temperature range of 185°F to 270°F. The DCPP post-LOCA containment temperature profile has temperatures lower than 185°F, but use of this temperature profile was deemed acceptable by Westinghouse. According to Westinghouse, "as the temperature falls below 140°F, the degree of conservatism increases, and the predicted material release results may be several orders of magnitude high at 'ambient temperature' (70°F)." Sensitivity calculations show that the post-LOCA containment temperature profile does not have a significant impact on precipitate formation (using the maximum postulated containment temperature for the duration of spray, vice using the profile, results in the formation of an additional 5 percent of aluminum oxyhydroxide).
- Duration and pH of CS.
- Containment aluminum inventory and location (submerged or unsubmerged in containment recirculation pool).
- Debris quantities in the recirculation pool (from Debris Generation Calculation). Plant specific debris density values are also used in the model. DCPP has not credited holdup of debris during the washdown phase of debris transport to reduce debris quantities in the recirculation pool. For DCPP specific debris types (i.e. Mica tape), Westinghouse has provided guidance on correctly inputting this debris into the model. The following types of debris are included in the DCPP chemical effects model:

- Temp-Mat
- Kaowool
- Cerablanket
- Mineral Wool (from elbows of pipe fittings)
- Glass Tape (fiberglass component of Mica tape)
- Calcium Silicate
- Marinite M Board
- Mica
- Aluminum Paint
- Aluminum Tape

- Recirculation pool volume. The WCAP-16530-NP model calculations were performed with both the maximum and minimum recirculation pool volumes, with the maximum volume being most conservative.

Some key assumptions used during the calculation of chemical precipitates include:

- A 20 percent margin was added to the aluminum inventory (except for aluminum paint).
- All components which are not submerged are wetted by CS (other than paint, which is only wetted if the RMI covering the paint is postulated to be destroyed in the Debris Generation Calculation).
- The recirculation pool is conservatively assumed to be at a maximum pH (9.5) instantaneously at the onset of CS. This is a conservative assumption, as higher pH values increase the aluminum release rate.
- CS pH is conservatively assumed to be the maximum possible (10), and CS duration was calculated to be 100 minutes (duration to exhaust sodium hydroxide solution in Spray Additive Tank). Using the maximum possible duration for CS is conservative, as unsubmerged aluminum corrodes only during the duration of CS.
- It is conservatively assumed that all fibrous latent debris is deposited in the recirculation pool and contributes to chemical precipitate formation.
- The aluminum tape (which is physically located above the recirculation pool water level) adhesive is postulated to fail in the post-LOCA environment. It is assumed that this tape enters the recirculation pool. Aluminum paint, which is also postulated to fail in the Debris Generation Calculation, is also assumed to enter the recirculation pool. This is conservative since total corrosion of aluminum over the WCAP-16530-NP model run time is greater in the recirculation pool than for aluminum which is strictly exposed to CS.

Refinements to WCAP-16530-NP Methodology

PG&E made one refinement to the WCAP-16530-NP methodology. The WCAP-16530-NP calculations provide two inputs for plant aluminum inventory (submerged mass and volume, and unsubmerged mass and volume). Much of the aluminum surface area in containment at DCPP is aluminum paint. Using the surface area of aluminum paint with the mass of the entire aluminum inventory allows aluminum corrosion calculations to continue using the large paint surface area long after the aluminum paint mass has been released into solution. Separating aluminum paint corrosion from aluminum component corrosion more accurately reflects aluminum release for precipitate formation. The WCAP-16530-NP model was modified to include four inputs for plant aluminum inventory (submerged mass and volume (components), unsubmerged mass and volume (components), submerged mass and volume (paint), and unsubmerged mass and volume (paint)). Westinghouse has verified DCPP's proper implementation of the WCAP-16530-NP methodology including the aforementioned refinement.

Calculated Precipitate Quantities

The calculated chemical precipitate quantities for the design verification head loss tests of record are summarized in the table below:

Head Loss Test[5]	Break Description	Chemical Precipitate Formation	
		Sodium Aluminum Silicate	Aluminum Oxyhydroxide
		(lbs)	(lbs)
8-S-PSG[1]	Loop 2 Crossover Leg Break at SG 1-2	95.17 (120.68)	128.84 (123.02)
9-S-PSG	Loop 2 Crossover Leg Break at SG 1-2	120.16	140.76
10-S-PSG	Loop 2 Crossover Leg Break at SG 1-2	120.16	140.76
11-S-PSG	Loop 2 Crossover Leg Break at SG 2-2	97.58	144.55
14-S-PSG[4]	Unit 1 Line 727 Break between PZR and 8010C valve	87.03	163.77[2]
15-S-PSG[4]	Loop 4 Crossover Leg Break at RCP 1-4	92.75	152.02[3]

[1]The chemical effects calculation for Test 8-S-PSG had an error in the spreadsheets (Marinite was not summing into the Calcium Silicate category). The correct precipitate quantities are shown in parenthesis.
[2]Head loss Test 14-S-PSG used an unscaled quantity of aluminum oxyhydroxide of 164.28 lbs. This number was based upon preliminary calculations, but was greater than the final calculated value (163.77). Hence, head loss Test 14-S-PSG was conservative with respect to aluminum oxyhydroxide precipitate debris.
[3]Head loss Test 15-S-PSG used an unscaled quantity of aluminum oxyhydroxide of 153.69 lbs. This number was based upon preliminary calculations, but was greater than the final calculated value (152.02). Hence, head loss Test 15-S-PSG was conservative with respect to aluminum oxyhydroxide precipitate debris.
[4]Head loss Tests 14-S-PSG and 15-S-PSG used aluminum oxyhydroxide in lieu of sodium aluminum silicate, as is allowed in WCAP-16530-NP.
[5]The chemical effects calculation for 14-S-PSG and 15-S-PSG utilized a more conservative post-LOCA sump pool temperature.

For a discussion on head loss testing with chemical effects, refer to Section 3.f, Head Loss and Vortexing.

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. 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.*

> *GL 2004-02 Requested Information Item 2(e)*
> *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.*

PG&E Response:

Changes to the licensing basis will be implemented in accordance with the requirements of 10 CFR 50.59, consistent with the extensions approved by the NRC in letters dated January 18, 2007 (Unit 2) and April 27, 2007 (Unit 1). The FSAR will be updated, consistent with the requirements of 10 CFR 50.71(e), to reflect changes made due to the sump evaluation or plant modifications required to resolve issues related to GL-2004-02.

The new containment recirculation sump screen design requires that the screen be submerged to provide sufficient NPSH and prevent air ingestion when the RHR pumps are started after switchover to the recirculation phase for the design basis LOCA. See Section 3.g, Net Positive Suction Head (NPSH). Amendment No. 199 to Facility Operating License DPR-80 and Amendment No. 200 to Facility Operating License DPR-82, for Units 1 and 2 respectively, revised TS 3.5.4, "Refueling Water Storage Tank (RWST)," Surveillance Requirement (SR) 3.5.4.2 to increase the minimum required borated water volume from, "≥400,000 gallons (81.5 percent indicated level)," to "≥455,300 gallons (93.6% level)" (PG&E Letter DCL-07-093, dated October 2, 2007). These amendments have been implemented for both units.

No other licensing actions are required to support changes to the licensing basis.