Progress Energy

Crystal River Nuclear Plant
Docket No. 50-302
Operating License No. DPR-72

Ref: 10 CFR 50.54(f)

February 29, 2008
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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Crystal River Unit 3 – Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

References:

1. NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004
2. CR-3 to NRC letter, "Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,'" dated August 30, 2005
3. NRC to CR-3 letter, "Request for Additional Information, RE: Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,'" dated February 9, 2006 (TAC NO. MC4678)
4. Letter from W.H. Ruland, Nuclear Regulatory Commission to A. Pietrangelo, Nuclear Energy Institute, "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," dated November 21, 2007
5. Letter from W.H. Ruland, Nuclear Regulatory Commission to A. Pietrangelo, Nuclear Energy Institute, "Supplemental Licensee Responses to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water reactors,'" dated November 30, 2007

Dear Sir:

Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02 (Reference 1) requested that addressees perform an evaluation of the emergency core cooling system (ECCS) and containment spray system (CSS) recirculation functions in light of the information provided in the GL and, if appropriate, take additional actions to ensure system function. Licensees were required to provide a response detailing their actions in accordance with 10 CFR 50.54(f). In Reference 2, Florida Power Corporation, doing business as Progress Energy Florida, Inc., Crystal River Unit 3 (CR3), provided this response to the GL as required.

CR-3 received a request for additional information (RAI) (Reference 3) based on the response to the GL. Subsequent to this RAI, the NRC submitted guidance (References 4 and 5) for the preparation of GL

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supplemental responses to the Nuclear Energy Institute (NEI) for industry distribution. This letter is being submitted in accordance with the guidance for supplemental responses in References 4 and 5.

This submittal contains no new regulatory commitments.

If there are any questions regarding this submittal, please contact Mr. Dennis Herrin, Acting Supervisor, Licensing and Regulatory Programs at (352) 563-4633.

Sincerely,

Dale E. Young

Dale E. Young
Vice President
Crystal River Nuclear Plant

DEY/seb

Attachment: GL 2004-02 Supplemental Response

xc: NRC Project Manager
NRC Regional Office
NRC Resident Inspector

STATE OF FLORIDA

COUNTY OF CITRUS

Dale E. Young states that he is the Vice President, Crystal River Nuclear Plant for Florida Power Corporation, doing business as Progress Energy Florida, Inc.; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission the information attached hereto; and that all such statements made and matters set forth therein are true and correct to the best of his knowledge, information, and belief.

Dale E. Young
Vice President
Crystal River Nuclear Plant

The foregoing document was acknowledged before me this 29th day of Feb., 2008, by Dale E. Young.

Signature of Notary Public
State of Florida

ELLEN DEPPOLDER
MY COMMISSION # DD 408539
EXPIRES: July 8, 2009
Bonded Thru Notary Public Underwriters

(Print, type, or stamp Commissioned Name of Notary Public)

Personally Known ✓ -OR- Produced Identification ______

PROGRESS ENERGY FLORIDA, INC.

CRYSTAL RIVER - UNIT 3

DOCKET NUMBER 50 - 302 / LICENSE NUMBER DPR - 72

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

GL 2004-02 Supplemental Response

GL 2004-02 Supplemental Response

Acronyms

AECL	Atomic Energy Canada Limited
AI	Administrative Instruction
AISC	American Institute of Steel Construction
ANSI	American national Standards Institute
ASME	American Society of Mechanical Engineers
BS	Building Spray
BWR	Boiling Water Reactor
BWST	Borated Water Storage Tank
CAD	Computer Aided Design
CF	Core Flood
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CR3	Crystal River Unit 3
CSHL	Clean Screen Head Loss
CS	Containment Spray (referred to as BS at CR3)
DBA	Design Basis Accident
DDTS	Drywell debris Transport Study
DH	Decay Heat
dP	Differential Pressure
ECCS	Emergency Core Cooling System
EFW	Emergency Feedwater
EM	Emergency Management Procedure
EOF	Emergency Operating Facility
EOP	Emergency operating Procedure
EPRI	Electric Power Research institute
FME	Foreign Material Exclusion
FSAR	Final Safety Analysis Report
FTC	Fuel Transfer Canal
GDC	Generic Design Criteria
GL	Generic Letter
GR	Guidance Report
GSI	Generic Safety Issue
HELB	High Energy Line Break
HPI	High Pressure Injection
ITS	Improved Technical Specifications
LBLOCA	Large Break LOCA
LOCA	Loss of Coolant Accident
LPI	Low Pressure Injection
MBLOCA	Medium Break LOCA
MU	Make-Up
NEI	Nuclear Energy Institute
NPSH	Net Positive Section Head
NRC	Nuclear Regulatory Commission
OTSG	Once Through Steam Generator
RB	Reactor Building
RCS	Reactor Coolant System
RFO	Refueling Outage
RG	Regulatory Guide
RMI	Reflective Metal Insulation
Rx	Reactor
SBLOCA	Small Break LOCA
SER	Safety Evaluation Report
SP	Surveillance Procedure
TKE	Turbulent Kinetic Energy
TSC	Technical Support Center
TSP	Tri-Sodium Phosphate
ZOI	Zone of Influence

Crystal River Unit 3 Supplemental Response to Generic Letter 2004-02

General Overview and Discussion:

Crystal River Unit 3's (CR3) strategy for resolution of Generic Safety Issue (GSI) -191 and Generic Letter (GL) 2004-02 issues consists of a variety of design and administrative features that are integrated into a very comprehensive, conservative approach. The overall strategy at CR3 includes much more than increasing the surface area of the Reactor Building (RB) sump strainer.

The physical design changes, relative to post-Loss of Coolant Accident (LOCA) long-term recirculation cooling, take advantage of the unique physical geometry of the CR3 (RB) floor layout. The fundamental intention of the physical modifications is to induce suspended, sliding, and/or tumbling post-LOCA debris to travel a tortuous, yet reliable, recirculation phase flow path in order to increase the likelihood of entrapment or capture. Optimizing bulk recirculation water flow characteristics minimizes the amount of debris actually reaching the sump and increases settlement in the relatively quiescent regions of containment. Additionally, the water inventory available to meet RB sump demand is assured by keeping recirculation flow paths unobstructed and hold-up minimized elsewhere in the building. The reactor core cooling is maintained by ensuring that Emergency Core Cooling System (ECCS)/Containment Spray System (CS) (referred to as Building Spray System (BS) at CR3) pump and other critical downstream component operations are not compromised by debris-laden fluid.

Administrative enhancements include such items as increased Foreign Material Exclusion (FME) control and awareness, injection flow rate reduction prior to switchover to sump recirculation, termination of unnecessary pumps and/or additional recirculation flow rate reductions, trending strainer debris accumulation via differential pressure monitoring, refilling the Borated Water Storage Tank (BWST) for backup inventory, backflushing a debris-laden strainer, and operator procedure training for each of these actions.

As an overview, CR3's strategy for resolution of GSI-191 includes the following:

1. Ensure adequate water inventory reaches the RB sump during long term recirculation cooling. This "upstream effects" improvement has been accomplished by:
   - Minimizing water holdup in areas of the RB (bio-shield compartments, Fuel Transfer Canal (FTC), intervening floors, etc.)
   - Ensuring credited water flow paths to the sump remain clear (FTC drain strainer, D-Ring gate, D-Ring scuppers)
   - Ensuring the BWST is depleted to pre-determined levels during the injection phase to support minimum water level assumptions

2. Optimize recirculation flow patterns to minimize debris transport by:
   - Minimizing water velocity and turbulence (new flow diverter installed at D-Ring exit)
   - Minimizing debris movement in recirculation pool (induce settling, limit sliding/tumbling)

3. Maximize debris entrapment and minimize debris transport to the sump by:
   - Providing interception in low turbulence regions (curbing at all D-Ring exits, Reactor Coolant (RC) drain tank room capture, a new debris interceptor in a low velocity flow path, a 4 inch high curb at the sump entrance, a new reactor cavity canal drain strainer, etc.)
   - Creating a long, torturous path for debris (labyrinth exit from D-Ring, perforated covers over the south D-Ring scuppers, shield plates in front of most of the scuppers, etc.)

4. Minimize head loss due to debris accumulation at the strainer, thus improving pump acquired net positive suction head ($NPSH_a$) by:
   - Increasing strainer surface area while utilizing a complex strainer geometry
   - Providing adequate debris mass capture (interstitial volume) without impacting effective strainer surface area (complex geometry induces non-uniform loading and avoids transition to the circumscribed area/footprint of the new strainer due to volume overload)

- Improving sump trash rack geometry to improve debris capture (increased horizontal trash rack surface area and added vertical surface area, previously unavailable)
- Removing mineral wool and NUKON insulation (potential debris sources)

5. Minimize latent debris source term by:
   - Improving RB close-out cleanliness/FME standards during outages
   - Continuing to remove degraded qualified coatings

6. Improve ECCS/Building Spray (BS) pump NPSH margin when taking suction from the RB Sump by:
   - Increasing the strainer surface area by a factor of 13 (from 86 ft^2 to 1139 ft^2)
   - Adding bell mouth shaped entrances to the sump outlet piping (reduces ECCS piping inlet losses)
   - Providing Regulatory Guide (RG) 1.97 qualified sump strainer differential Pressure (dP) measurement capability for debris accumulation and head loss trending purposes
   - Terminating High Pressure Injection (HPI) pumps during BWST depletion if adequate Low Pressure Injection (LPI) flow in each train is verified. This has multiple benefits, such as:
     - o reduces flow through each LPI pump – i.e., no piggy-back operation,
     - o reduces total flow/head loss across the strainer,
     - o reduces suction line velocity induced head loss, delays switchover to recirculation to enhance settlement, and
     - o reduces debris transport via bulk water velocity reduction to the sump.
   - Assuming NPSH margin calculations for all HPI/LPI/BS pumps account for operation at error-adjusted (upward) design basis flow rates and share train-common suction lines, whereas recirculation demand would actually be approximately 1160 gpm lower (~13%) than the total sump flow rate used in the analyses (~8700 gpm, Reference 14)
   - Terminating a BS pump, after switchover, if RB fan cooling is functioning properly. This has similar benefits to the above by reducing flow to the sump, through the strainer, and to the common train LPI pump sharing the terminated BS pump's suction line by about 1360 gpm (~15% reduction from the flow rate analyzed for NPSH purposes)
   - Continuing to enforce the requirement of reducing LPI and BS pump flows (via appropriately designed throttle valves) prior to switchover from the BWST
   - Ensuring strainer is completely submerged at onset of recirculation, with the submergence depth exceeding the maximum expected strainer head loss. This maximizes strainer effectiveness while minimizing the potential for air ingestion or bubble formation (vortexing, vaporization)

7. Decrease strainer opening size to minimize detrimental effects on downstream equipment by:
   - Reducing strainer opening size from ¼ inch square mesh screen to 1/8 inch diameter holes.

8. Improve LPI and CS pump seal reliability by installing new cyclone separator assemblies that do not require throttle valves (which are potential blockage locations) to maintain seal water quality via separator debris removal efficiency.

9. Improve procedural guidance reflecting the new sump design and other related modifications and compensatory actions. This includes:
   - Monitoring/trending RB sump strainer head loss during recirculation in order to determine if pump operation could be challenged. Potential compensatory actions have been prescribed as discussed below.
   - Refilling the BWST and aligning HPI pumps for additional injection, if necessary
   - Terminating unnecessary pump operation, as discussed previously
   - Performing RB closeout inspections that ensure flow paths are clear
   - Establishing Accident Assessment Team (TSC/EOF) guidance such as:
     - o Back-flushing the sump strainer (new strainer designed for gravity drain loads)
     - o Provisions for core decay heat boil-off matching flow vs. time curves
     - o Terminating unnecessary ECCS/CS pump operation
     - o Consideration/preparation of alternate injection sources

- Initiate an active boron precipitation method within 48 hours to limit scale buildup on fuel rods

In summary, based on the enhancements and conservatisms discussed above, and following completion of insulation replacement activities in 2009, CR3 will be in full compliance with the intentions of GSI-191. Long term post-LOCA ECCS and CS functions under fully loaded debris conditions are ensured, as required by 10CFR50.46 and the appropriate General Design Criteria (GDC) with confidence.

Note: CR3 served as a volunteer pilot plant for NRC GSI-191 Resolution and GL 2004-02 activities (Reference 1, 2, 3, and 9). Much of the information provided herein has been reviewed by the NRC staff and can be supplemented by the CR3 Pilot Plant Audit Report submitted to James Lyons, Director, Division of Systems Safety and Analysis, NRR, dated June 29, 2005 (Reference 4). CR3 provided nearly all the analytical and physical design information relative to GL 2004-02 for NRC Staff review as part of the pilot plant effort. Design changes with most hardware modifications were implemented in November 2005 during Refueling Outage 14 (RFO-14). Subsequent hardware modifications, i.e., cyclone separator upgrades to the LPI and BS pump seal injection paths, were completed in 2007 (References 54 through 57).

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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 and CS 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.***

Revises previous information:

The overall strategy for resolution of GSI 191 and GL 2004-02 issues at CR3 includes physical plant changes, administrative enhancements, and development of general station awareness, that collectively provide assurance that long term ECCS and CS recirculation functions operate reliably and safely. The design changes take advantage of the unique physical geometry and features of the CR3 containment. The basic intent of the physical modifications that have been performed is to induce suspended, sliding, and/or tumbling post-LOCA debris to travel a tortuous, yet dependable, recirculation-phase flow path that increases the likelihood of entrapment and optimizes the water flow profile characteristics such that debris reaching the sump are minimized through settlement in the relatively quiescent regions of the containment pool. Additionally, the recirculation water inventory available to the ECCS/CS pumps is abundant and cleansed, ensuring that pump operation and downstream flow paths are not compromised by debris-laden fluid.

As a result, following removal of fiber insulation inside the containment D-Rings, CR3 will be in full compliance with the ECCS and CS recirculation functions under debris loading conditions in accordance with the regulatory requirements detailed in GL 2004-02. The functional requirements of 10CFR50.46 and the GDC's are specified in the CR3 Final Safety Analysis Report (FSAR). CR3 requires long term RB sump recirculation to support ECCS (Make Up [MU]/Decay Heat [DH] systems) cooling requirements per 10CFR50.46 and to support CS (BS system) in accordance with the July 1967 draft 10CFR50.34 Appendix A, "General Design Criteria for Nuclear Power Plant Construction Permits," as discussed in Section 1.4 of the FSAR. Specifically, FSAR Section 1.4.42 (Criterion 42) requires the performance of Engineered Safeguards (ES) features to be designed to function, without impairment, due to the effects of a LOCA. Section 1.4.44 (Criterion 44) details the ECCS requirements and Section 1.4.52 (Criterion 52) details the post-LOCA containment heat removal requirements, which include the CS requirements. In addition, the CS will be fully capable of reducing the accident source term to meet the limits prescribed in 10 CFR 50.67 (FSAR Section 1.4.62, Criterion 62). FSAR Sections 6.1 and 6.2 discuss the ECCS/CS design basis requirements.

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>Revises previous information</u>:

General description of Corrective Actions:

The following modifications were completed during RFO-14 (Fall 2005):

1) <u>Sump strainer</u>: The original ¼ inch square mesh sump screen (86 ft^2 of flat plane screened area) was replaced with a complex geometry sump strainer (Enercon top hats) that has an effective surface area of 1139 ft^2 and 1/8 inch diameter perforations. The larger strainer assembly ensures that ECCS/CS NPSH margin is assured, even when considering the amount of post-LOCA debris that has the potential to reach and accumulate at the sump.

2) <u>Strainer trash rack</u>: The containment sump trash rack was increased in size from approximately 55 ft^2 of horizontal surface area to approximately 100 ft^2 of horizontal and 15 ft^2 (25 lineal feet) of vertical surface areas. The larger trash rack surface area is more tolerable of large debris capture, while the added vertical sections preclude the possibility of a large piece of debris (insulation panel, plastic sheet, etc.) from excessively obstructing the flow to the strainer below and potentially starving ECCS/CS pump demand.

3) <u>Flow distributor</u>: To further optimize the post-LOCA containment pool flow characteristics and induce sedimentation of debris, a flow distributor was added to minimize localized flow streaming and to reduce bulk recirculation flow turbulence. The flow distributor acts as a baffle, providing a regulated flow through a pre-engineered orifice opening, forcing the remaining flow around the distributor. The net effect is that the bulk fluid stream, downstream of the distributor, is improved into a somewhat homogenous, low-velocity, and relatively quiescent flow pattern, thus minimizing turbulence that could prolong debris suspension.

4) <u>Debris Interceptor</u>: A 15 inch high stainless steel debris interceptor was installed across the entire width of the RB floor between the D-Ring wall and the containment liner, to enhance the capability to trap sliding/tumbling floor debris that has settled in this low turbulence portion of the recirculating flow path.

5) <u>Scupper covers</u>: There are eight 1 foot x 1 foot scuppers that permit flow through the D-Ring and RC drain tank room walls, then around the D-Ring walls to the sump. Stainless steel plate bored with 3/16 inch perforations were added to the four scuppers located on the south D-Ring wall (which is physically nearer the sump).

6) Refueling Cavity Drain Trash Rack: A box-shaped trash rack with a 5-sided through-flow strainer surface area of about 8.5 ft^2 was installed over the 6 inch diameter drain path to the Reactor vessel cavity.

7) RB Sump Level Instrumentation Enhancements: The original Regulatory Guide 1.97 Sump Level indicator, a ball float style device, remains as a back-up to a new Rosemount dP cell that was installed as an enhancement. The dP cell provides the required post-accident sump level indication for the plant operator and also provides the capability for the Operator and Accident Assessment teams to trend the dP effects of debris accumulation on the sump strainer.

The following modifications were recently completed (2007):

1) LPI and CS Pump Seals: The LPI and BS pumps Borg-Warner cyclone separators have been replaced with ones manufactured by Crane, eliminating the throttle valve restrictions associated with the previous design and eliminating the potential for debris disrupting the seal cooling flow.

2) Fibrous Insulation Replacement: CR3 reduced the amount of NUKON fiber in the RB by 40 ft^3 by replacing the Pressurizer Head insulation with Reflective Metal Insulation (RMI). The amount of mineral wool fiber was also reduced by removing the majority of insulation on the steam generator blowdown lines.

3) Aluminum Inventory Reduction: Over 800 lbs of aluminum was removed from containment by replacing storage box covers with stainless steel.

4) Floor Drain Debris Screens: Perforated plate (3/16 inch holes) screens were installed in the Reactor Building floor drains to limit the transport of debris from remote areas of containment to the sump area.

The following administrative changes have been completed:

1) Operator Training on Sump Blockage: Licensed Operator training has been conducted on indications available for recognition of containment sump screen blockage and appropriate response measures. The operator training lesson plan includes monitoring of the operating ECCS and BS pumps for indications of pump distress or loss of NPSH, such as erratic motor current or pump flow and includes monitoring the sump screen differential pressure. The training emphasizes the use of all available instrumentation to identify symptoms of containment sump blockage or degraded ECCS or BS pump performance. This includes an upgrade to the plant simulator to include sump screen blockage scenarios.

2) Inventory Replenishment: Multiple and diverse sources to refill the BWST and inventory to inject into the Reactor Coolant System (RCS) have been established. CR-3 has revised Emergency Procedure series EM-225 to begin refilling the BWST as soon as possible following completion of the ECCS/BS pump suction switchover to the RB sump. Refilling the BWST will provide additional ECCS inventory for RCS injection and/or backflushing in the unlikely event that severe RB sump screen blockage occurs.

3) Containment Cleanliness: Aggressive containment cleaning and increased foreign material controls have been established. Surveillance Procedure, SP-324, "Containment Inspection," has been revised to require more detailed RB inspections following an outage. This includes separate areas of the RB being inspected by teams typically led by Senior Reactor Operators. This procedure also performs verification of drainage path availability for all RB floor drains and the two (2) FTC drains. This procedure provides instructions to inspect the RB after a maintenance outage, quarterly inspections or limited maintenance jobs which require entry into containment. This procedure contains instructions to ensure no latent debris is present which can be carried to the containment sump. It also serves to ensure post-LOCA recirculating water flow paths are open and unobstructed.

4) Housekeeping: Training has been provided to the Maintenance organization on the importance of RB cleanliness towards the minimization of latent debris that could affect sump recirculation, and

thus post-accident core cooling capabilities including enforcement of the use of mats and/or tarps for work activities occurring over open floor grating to minimize the spread of foreign material to lower building elevations. In addition, a checklist item to discuss housekeeping requirements for work inside the RB has been added to Administrative Instruction, AI-607, "Pre-job and Post-job Briefings."

5) Sump Strainer Inspections: CR3 verifies the integrity of the RB sump on a refueling outage interval of 24 months with the performance of Surveillance Procedure SP-175A, "Reactor Building Emergency Sump Inspection and Cleaning." The procedure requires 100% inspection of each top-hat, surrounding interstitial spaces (space between top-hats and vertically down center of top-hats) and above and below the screen structure, including the inspection of all fasteners, minimal corrosion of all components, and no evidence of debris in or around the sump or ECCS suction piping prior to declaring the sump operable following a refueling outage.

6) Modification Procedure: Engineering Change screening criteria includes questions that require the engineer to determine if the change will create or alter the potential sources of debris which could interfere with ECCS suction from the RB sump, and if the change will result in the addition of materials in containment that could affect post-accident chemical precipitation. This aids in preventing the introduction of materials into containment that are potentially detrimental to ECCS recirculation.

7) Backflush Procedure: To address the possibility of high sump screen differential pressure and sump screen blockage, diverse contingency actions including backflush of sump screens are written into EM-225E, "Guidelines for Long Term Cooling." The actions in this procedure are cued by indications of RB sump strainer blockage in Emergency Operating Procedures (EOPs). Indications of possible blockage include fluctuating flow rate and/or pump motor amps, as well as increasing differential pressure indication across the sump screen. None of the methods to address sump screen blockage interrupt flow to the core.

Additional Corrective Actions:

CR3 submitted a request for extension of the completion date for corrective actions and modifications required by GL 2004-02 (Reference 71). The NRC granted this request (Reference 72), concluding that CR3 has put mitigation measures in place to adequately reduce risk for an approximate 21 month extension period to complete the following corrective actions:

Insulation Replacement: CR3 intends to replace all of the encapsulated mineral wool insulation in the LOCA zone of influence within the D-Rings (High Energy Line Break [HELB] zones) with RMI coincident with the once-through steam generator (OTSG) replacement effort (RFO 16). In addition, the remaining 10 ft^3 of NUKON insulation will also be replaced with RMI (although head loss analyses and testing assume that the 10 ft^3 of NUKON will remain). The new steam generators will also be provided without the high heat aluminum paint that exists on the current steam generators.

This mineral wool removal effort, along with the Pressurizer Head insulation replacement, and the OTSG aluminum paint elimination, will result in debris source term reductions of:

- NUKON fiber (from 50 ft^3 to 0 ft^3)
- Mineral Wool fiber (from 306 ft^3 to 0 ft^3)
- Unqualified High Heat Aluminum Paint (from 1485 ft^2 to 479 ft^2 of 10 μ particulate loading)

3. Specific Information Regarding Methodology for Demonstrating Compliance:

a. 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.***

Revises previous information:

Basis for Break Selection Criteria:

Large Break LOCAs (LBLOCAs) and a certain range of Small Break LOCAs (SBLOCAs, 2-1/2 inch schedule 160 pipe and larger) are the only CR3 high energy line break events that may rely on sump recirculation to mitigate the accident. The objective of the break selection process is to determine the break size and possible locations that could result in the greatest debris generation and/or the debris generation that presents the greatest challenge to post-accident sump performance. With the accident scenarios requiring ECCS sump operation being identified, piping break locations that could lead to ECCS sump operation were identified. This was accomplished through a review of the system flow or process and instrumentation diagrams and piping isometric or other layout drawings.

The NEI PWR Sump Performance Methodology (GR) recommends that a sufficient number of breaks in each system that relies on recirculation be considered to ensure that the breaks that bound variations in debris generation by the size, quantity, and type of debris are identified. The following break locations were considered:

- Break No. 1: Breaks in the RCS with the largest potential for debris.
- Break No. 2: Large breaks with two or more different types of debris.
- Break No. 3: Breaks in the most direct path to the sump.
- Break No. 4: Large breaks with the largest potential particulate debris to insulation ratio by weight.
- Break No. 5: Breaks that generate a "thin bed" – high particulate with 1/8 inch fiber bed.

Secondary System Line Breaks:

Secondary plant system line breaks were not considered in this CR3 evaluation. Secondary system line break evaluations (Main Steam, Feedwater, Emergency Feedwater, etc.) do not credit RB cooling fan or Building Spray system operation for recovery, therefore sump recirculation is not necessary to mitigate the effects of these breaks.

Refer to the Pilot Plant Audit Report (Reference 4) for additional detail regarding Staff review and concurrence with this conclusion.

Bounding Break Determination for Sump Performance:

Large Break LOCAs:

The CR3 FSAR classifies LBLOCAs as >0.75 ft^2 cross sectional break area (11 ¾ inch ID Pipe). These events could result in full Engineered Safeguards actuation, which initiates 2 Make-Up (MU) pumps, 2 Decay Heat (DH) pumps and 2 Building Spray (BS) pumps. Core Flood (CF) tanks will dump at approximately 600 psia directly into the vessel, adding a nominal 15,000 gallons to the Reactor Building through the break. The full spectrum of LBLOCAs requires sump operation. A review of CR3 drawings was performed to identify those lines >11 inch directly attached to the RCS (evaluated up to the Class 1/Class 2 boundary interface).

The LBLOCA lines included were:

- 36 inch RCS (hot leg)
- 28 inch RCS (cold leg)
- 14 inch CF up to valve CFV-1 and CFV-3
- 12 inch DH up to valve DHV-3

Locations of these LBLOCA lines are:

- RCS Hot and Cold Legs: Inside the North and South D-Rings
- 14 inch CF up to CFV-1 and CV-3: Inside the North and South D-Rings
- 12 inch DH up to DHV-3: Inside the South D-Ring

Small Break LOCAs:

The CR3 FSAR classifies SBLOCAs as the break of any RCS or connecting pipe in excess of MU pump capacity up to 0.75 ft^2 (which includes Medium Break LOCAs). Since SBLOCAs may not be able to be isolated, they must still be considered for debris generation, as many of these accidents can eventually lead to recirculation. Only SBLOCA lines 2 ½ inch outer diameter (OD) and larger (up to 11 ¾ inch inner diameter [ID]) are included in this evaluation – no instrument lines or smaller taps are addressed. This is consistent with the methodology set out in the Safety Evaluation Report (SER) for NEI 04-07.

The SBLOCA lines included were:

- 10 inch Pressurizer Surge Line
- 2 ½ inch Pressurizer Spray Line
- 2 ½ inch RCS Letdown to Containment penetration
- 2 ½ inch HP Injection from MU to MUV-42 and MUV-43
- 2 ½ inch HP Injection from MU to MUV-36 and MUV-37

Locations for these SBLOCA lines were:

- 10 inch Pressurizer Surge Line: Inside North D-Ring
- 2 ½ inch Pressurizer Spray Line: Inside North D-Ring
- 2 ½ inch RCS Letdown: Inside South D-Ring, Letdown Heat Exchanger Room, Outside South D-Ring & over Containment Sump
- 2 ½ inch HP Injection from MU to MUV-36: Inside South D-Ring
- 2 ½ inch HP Injection from MU to MUV-37: Inside South D-Ring
- 2 ½ inch HP Injection from MU to MUV-42: Inside North D-Ring
- 2 ½ inch HP Injection from MU to MUV-43: Inside North D-Ring

Through iterative processes, the break location determined to provide the greatest challenge to post-LOCA sump performance is a Hot Leg Break (36 inch NPS LBLOCA) inside the North D-Ring. This break location results in the potential for creating the maximum debris loading condition at the sump, combined with the highest recirculation flow rate across the sump strainer. This location was determined to encompass and bound both Break Nos. 1 and 2. Break No. 4 is not applicable to CR3 since no equipment insulations are particulate types, thus Break No. 4 (the maximum particulate/fiber ratio) is bounded by Break No. 5 (thin bed). Prototypical head loss testing has shown that insufficient insulation and latent fiber exists to provide complete strainer coverage. Therefore, a break that generates a thin bed does not exist, and Break No.1 is the bounding break.

The limiting break location providing the most direct route for debris to the sump (Break No. 3) was determined to be a letdown line break (2-1/2 inch SBLOCA) in the vicinity of the sump. This break results in lower debris loading and a lower recirculation flow rate across the strainer. This condition is easily bounded by the LBLOCA break condition (Break No. 1), when related to sump performance.

The following tables provide the maximum debris quantities predicted to be generated by the bounding break locations (Break Nos. 1 and 3), for comparison:

RCS Hot-Leg Double-Ended Guillotine Break Debris Generation
Break No.1[1]

Insulation Type	North D-Ring
RMI	7341 ft^2
Mineral Wool (4D ZOI)	0 ft^3
Mineral Wool (17D ZOI)	0 ft^3
NUKON®	10 ft^3

RCS Letdown Line Zones
Break No. 3

Insulation Type	Zone 110	Zone 118	Zone 120
RMI	0 ft^2	62 ft^2	60 ft^2
Mineral Wool	0 ft^3	0 ft^3	3 ft^3
NUKON®	1 ft^3	0 ft^3	0 ft^3

[1] Debris source term values reflect post-steam generator replacement conditions. Following steam generator replacement, it is expected that no fiber insulation will remain installed in any LBLOCA Zone of Influence (ZOI). However, current analyses assume 10 ft^3 of NUKON insulation will remain for conservatism.

b. 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.***

Revises previous information:

- Methodology for ZOIs:

  The methodology from NEI 04-07 (SER) and the NEI PWR Sump Performance Methodology (GR) has been used for ZOI determination, unless noted otherwise in the following discussions.

- ZOI, by constituent (values from the NRC SER – Reference 9, unless shown otherwise):

ZOI Radii for CR3 Insulation and Coating Materials

Insulation Types	Destruction Pressure (psi)	ZOI Radius (Radius/Break Diameter) Value Used at CR3
Design Basis Accident (DBA) Qualified Epoxy Coatings	WCAP-16568-P (Ref 52)	4.0
Mirror® with Sure-Hold® Bands	90	2.4
Unjacketed NUKON® Jacketed NUKON® with standard bands	6	17.0
Mineral Wool Jacketed with 22 or 24 gauge 304 ss (MS, FW, EFW Only)	Similar to RMI cassettes with latches	4.0 (vs. 2.4)*
Mineral Wool Encapsulated in 22 Gauge Corrugated Sheet Cover (SG and BD Only)	6	17.0*
Mirror® with standard bands	2.4	28.6

*Mineral Wool:

Neither the NEI 04-07 GR nor the SER provided a destruction pressure for Mineral Wool. Mineral Wool is classified as a fibrous type insulation. It is slightly denser than fiberglass (>4 lbm/ft^3 vs. 2.4 lbm/ft^3).

The Mineral Wool at CR3 on the Main Steam, Feedwater, and Emergency Feedwater piping is also fully encapsulated within stainless steel cassettes. The Mineral Wool cassette system used at CR3 is virtually identical to that of Transco RMI (22 or 24 gauge 304 stainless steel), but with a different filler material, i.e., mineral wool fibers instead of metal foils. Based on the robust nature of this fibrous insulation system, the ZOI for mineral wool is closer to that of Transco RMI (2.4 D) than that of NUKON® (17.0 D). The jacketing system, which includes latches and buckles, significantly increases the destruction pressure required. The filler material, whether it is foils or fibers, does not contribute to the overall strength of the product. It is for this reason that the destruction pressure of the mineral wool cassette and the Transco RMI cassette are considered equal, with the difference being the size distribution of the filler material. However, the ZOI for the mineral wool system was increased from 2.4D to 4.0D as a conservative measure.

The mineral wool installed on the steam generator shell and the steam generator blowdown piping is not encapsulated in stainless steel jacketing. The steam generator shell mineral wool is encapsulated in 0.002 inch foil with an external 22 gauge corrugated sheet cover. A 17D ZOI for mineral wool was applied to the steam generator shell and blowdown piping insulation based on this type of jacketing.

Following insulation replacement efforts in Refuel Outage 16 (Fall 2009), the only mineral wool insulation remaining in a RCS ZOI will be in the vicinity of the letdown line outside the D-Rings. A ZOI of 17D is applied to the mineral wool at this location.

- Destructive testing for ZOI establishment

  No CR3-specific destructive testing was accomplished for ZOI determinations. However, jet impingement testing was performed by Westinghouse to determine the ZOI for DBA-qualified coatings (Reference 52).

- Debris types and quantities

  The following tables summarize the amount of debris generated by break type:

Fibrous Insulation Debris Source Term – LBLOCA[2]

Insulation Type	Total Amt. Destroyed	Fines (individual fibers)	Small pieces (< 6" on a side)	Large Exposed (Uncovered) Pieces
Mineral Wool	0 ft^3	0 ft^3	0 ft^3	0 ft^3
NUKON®	10 ft^3	2 ft^3	8 ft^3	NA

Reflective Metal Insulation Debris Source Term – LBLOCA

Total Amount Destroyed	Density	Amount Destroyed by Size Distribution					
		¼"	½"	1"	2"	4"	6"
7341 ft^2	484 lbm/ft^3	316 ft^2	1483 ft^2	1534 ft^2	1879 ft^2	1233 ft^2	896 ft^2

[2] Debris source term values reflect post-steam generator replacement conditions. Following steam generator replacement, it is expected that no fiber insulation will remain installed in any LBLOCA ZOI. However, current analyses assume 10 ft^3 of NUKON insulation will remain for conservatism.

Fibrous Insulation Debris Source Term – SBLOCA

Insulation Type	Total Amt. Destroyed	Fines (individual fibers)	Small pieces (< 6" on a side)
Mineral Wool	3 ft^3	0.6 ft^3	2.4 ft^3
NUKON®	0 ft^3	0 ft^3	0 ft^3

Reflective Metal Insulation Debris Source Term – SBLOCA

Total Amount Destroyed	Density	Amount Destroyed by Size Distribution					
		¼"	½"	1"	2"	4"	6"
60 ft^2	484 lbm/ft^3	3 ft^2	12 ft^2	13 ft^2	15 ft^2	10 ft^2	7 ft^2

- Miscellaneous Materials:

Failed Coating Debris Source Term

Coating Description	Failed Surface Area (ft^2)	Applied Thickness	Volume (ft^3)	Density (lb/ft^3)	Weight (lbs)	Failed Size
Plasite 9028 MI	1809.6	8 mil	1.21	119.8	144.5	10 μ
Plasite 9009	1809.6	8 mil	1.21	95.5	115.6	10 μ
Hi-Heat Aluminum	479	0.75 mil	0.03	90	2.7	10 μ
Unqualified Coatings	1000	6 mil	0.5	94	47.0	25 μ
Failed D-Ring 9028MI	9066	8 mil	6.04	119.8	723.6	25 μ
Failed D-Ring 9009	9066	8 mil	6.04	95.5	576.8	25 μ

Latent Debris Source Term

Latent Debris Type	Reactor Building Area				
	El 95'-0"	El 119'-0"	El 160'-0"	North D-Ring	South D-Ring
Labels – Adhesive Labels	309 Labels (19.3 ft^2)	903 Labels (56.4 ft^2)	107 Labels (6.6 ft^2)	875 Labels (54.6 ft^2)	750 Labels (46.8 ft^2)
Tags – Ceramic hanging Tags	298 Tags (69.8 ft^2)	397 Tags (93.0 ft^2)	23 Tags (5.4 ft^2)	75 Tags (17.5 ft^2)	60 Tags (14.0 ft^2)
Marinite and Fire Boards	In Cable Tray* near ceiling	In Cable* Trays	NA	NA	NA
Radiant Shields	Yes*	None	NA	NA	NA

* Marinite, Fire Boards, and Radiant shields are not located in any ZOI and do not contribute to latent debris loads.

Latent Debris Type	Mass (lbm)	Density	Size
Dirt & Dust	170	169 lbm/ft3	5.68 E-05 ft
Latent Fiber	30	94 lbm/ft3	2.3 E-05 ft

c. 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.***

Revises previous information:

- Size Distribution

Size Distribution

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	0%	4.3% (1/4" pieces) 20.2% (1/2" pieces) 20.9% (1" pieces) 25.6% (2" pieces)	16.8% (4" pieces) 12.2% (6" pieces)	0%
NUKON™	20% (individual fibers)	80% (<6" pieces)	0% (>6" pieces)	0% (intact blankets)
Mineral Wool	20% (individual fibers)	80% (<6" pieces)	0% (>6" pieces)	0% (intact blankets)
Qualified Plasite 9028 MI Coatings (inside ZOI)	100% (particulate)	0%	0%	0%
Qualified Plasite 9009 Coatings (inside ZOI)	100% (particulate)	0%	0%	0%
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	100% (particulate)	0%	0%	0%
Unqualified Coatings (outside ZOI)	0%	100% (chips)	0%	0%
Degraded Plasite 9028 MI Coatings (outside ZOI)	0%	100% (chips)	0%	0%
Degraded Plasite 9009 Coatings (outside ZOI)	0%	100% (chips)	0%	0%
Dirt/Dust	100% (particulate)	0%	0%	0%
Latent Fiber	100% (individual fibers)	0%	0%	0%

- Bulk densities and Material densities

Mineral Wool - is classified as a fibrous type insulation. A bulk density of 8 lbm/ft^3 is used per the original CR3 insulation specification (Reference 53). Vendor data provides a density for mineral wool fiber of 2.7 – 2.9 g/cm^3, which is conservatively taken to be 180 lbm/ft^3. The GR provides a mineral wool debris characteristic fiber diameter of 2.8 E-04 inches. This information is further substantiated by Scanning Electronic Measurement images of CR3 specific Mineral Wool (Reference 20, Attachment B).

NUKON - the properties are taken from NUREG/CR-6224 and the GR. The NUKON® debris has a bulk density of 2.4 lbm/ft^3, a microscopic density (glass fiber) of 175 lbm/ft^3, and a characteristic fiber diameter of 2.8 E-04 inch.

Coatings – refer to "Failed Coating Debris Source Term" in the previous table.

Latent Debris – referring to the latent debris source term characteristic table in the previous section, dirt and dust is assumed to have a material density of 169 lbm/ft^3 and a size of 5.68 E-05 ft. Latent fiber is assumed to have a material density of 94 lbm/ft^3, a bulk density of 2.4 lbm/ft^3, and a diameter of 2.3 E-05 ft.

- Specific surface areas

The specific surface areas for fibrous and particulate debris are generally used in the prediction of head loss with the NUREG/CR-6224 correlation. CR3 does not use the NUREG/CR-6224 (correlation to determine the debris bed head loss) and therefore the specific surface area is not applicable.

- Deviations

No destruction pressure is published for Armaflex insulation. Therefore, 100% of the Armaflex in the HELB compartment was assumed to fail. However, Armaflex is a closed cellular insulation material, and the 6 lbm/ft^3 debris fragments, which have very low moisture permeability, will float in water. Since the CR3 ECCS sump screen is submerged, well below the water line, and surface vortices have been evaluated to not develop, Armaflex debris will not contribute to the debris bed.

d. 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.***

Revises previous information:

- Two samples of latent debris were taken during RFO-13 (2003), from areas identified as coated with a heavy layer of dirt and dust. These samples quantified 1.65 g/ft^2 in one area and 1.41 g/ft^2 in the other. The GR includes an Appendix B in which dust and dirt samples of "clean" surfaces were determined to be covered with approximately 0.018 g/ft^2 of dust and dirt.

  CR3 used a latent debris loading of 1.65 g/ft^2 for areas graded as "Heavy Layer of Dirt and Dust," 1.41 g/ft^2 for areas graded as being "Dusty," and 0.018 g/ft^2 for the mopped clean floors. This is conservative as the 1.41 g/ft^2 for areas graded as being "Dusty" was obtained for a sample from an area considered "Heavy Layer of Dirt and Dust." Estimates of surface area were made to calculate a general latent debris source term for CR3. The Reactor Building horizontal surface area was calculated based on a 135 ft diameter. To account for equipment and cable tray surface areas, no credit for reduction in surface area from vertical walls or floor penetrations were taken.

  Based on CR3 cleanliness practices, "Clean" was applied to accessible areas on all levels and floors, and "Dusty" was applied to inaccessible areas, piping and cable trays. When assuming 50% of the total surface area "Clean," 30% "Dusty," and 20% "Heavy Layer of Dirt and Dust," which is conservatively biased towards the dirty scale, the calculated particulate latent debris source term = **72 lbs**.

  The SER, in Section 3.5.2, recommends as an approach to estimate buildup on vertical surfaces that 30 lbs be added to the horizontal quantity. This approach was utilized; 72 lb + 30 lb = 102 lb. To further account for uncertainties and to provide a very conservative bounding estimate for the dust, dirt, and latent fiber source term at CR3, **200 lb** is assumed to bound CR3 containment latent debris.

  As a follow-up to NRC comments during the Pilot Plant audit, additional samples (8) were gathered from "Dirty and Dusty" areas of containment during the RFO-14 (2005) outage. Extrapolation of the densities from these samples further supported a maximum expected loading of less than 100 lbs without applying more rigorous standards. Therefore, it is further concluded that the **200 lb default value** used at CR3 is appropriate and very conservative. It is assumed that 15% of the latent debris is fiber, consistent with guidance in the SER, Section 3.5.2.3.

- Summary of Latent Debris (same table as in previous section)

Latent Debris Type	Reactor Building Area				
	El 95'-0"	**El 119'-0"**	**El 160'-0"**	**North D-Ring**	**South D-Ring**
Labels – Adhesive Labels	309 Labels ($19.3\ ft^2$)	903 Labels ($56.4\ ft^2$)	107 Labels ($6.6\ ft^2$)	875 Labels ($54.6\ ft^2$)	750 Labels ($46.8\ ft^2$)
Tags – Ceramic hanging Tags*	298 Tags ($69.8\ ft^2$)	397 Tags ($93.0\ ft^2$)	23 Tags ($5.4\ ft^2$)	75 Tags ($17.5\ ft^2$)	60 Tags ($14.0\ ft^2$)
Marinite and Fire Boards**	In Cable Tray near ceiling	In Cable Trays	NA	NA	NA
Radiant Shields**	Yes	None	NA	NA	NA

*Ceramic tags are stainless steel with a ceramic coating, and are not assumed to transport to the sump.
** Marinite, Fire Boards, and Radiant shields are not located in any ZOI and do not contribute to latent debris loads.

Latent Debris Type	Mass	Density	Size
Dirt & Dust	170 lbm	$169\ lbm/ft^3$	5.68 E-05 ft
Latent Fiber	30 lbm	$94\ lbm/ft^3$	2.3 E-05 ft

- Sacrificial Strainer Area

CR3 has allotted 89 ft^2 for labels and miscellaneous latent material and items that could be overlooked or inadvertently left inside containment during closeout and startup efforts (Reference 20). Of this 89 ft^2, 47 ft^2 is assumed to be covered by labels, and includes 100% of the adhesive labels from within the North (most limiting) D-Ring, as well as 10% of the labels outside of the D-Rings. The label coverage area includes an overlap ratio of 0.75 as allowed by the SER. The remainder of the 89 ft^2 provides extensive margin for unaccounted latent debris, such as plastic sheets, bags, rags, paper tags, tape, etc., considering the quality of containment closure inspections (References 40, 43, 44, and 45). Therefore, the debris laden strainer head loss calculation assumes that only 1050 ft^2 of the 1139 ft^2 strainer area is available for LOCA generated debris.

e. 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.***

Revises previous information:

CR3 Calculation M90-0023 (Reference 15) determines, among other objectives, the minimum predicted post-LOCA containment/sump pool water inventory. Several conditions were evaluated to determine bounding parameters for each specific circumstance. The minimum water level was determined to be 2.12 feet for LBLOCA NPSH purposes and 2.04 feet for debris transport purposes. The difference in the two evaluations is a function of water and steam environment temperatures. The limiting LBLOCA NPSH condition is the lowest saturated steam environment temperature that could occur (204.7°F, based on the Improved Technical Specifications (ITS) minimum containment pressure prior to the HELB), thereby maximizing head loss across the sump strainer and the ECCS/CS pump suction piping. The limiting debris transport condition is the highest steam temperature environment expected, in order to maximize the amount of water vapor holdup outside the water pool and further minimize the pool height. This was conservatively determined to be a 240°F steam space, based on containment analysis case studies (Reference 15). The debris transport analysis (Reference 18) uses a water depth of 2.00 feet for recirculation transport, which is conservative.

CR3 applied the approach described in the NEI 04-07 guidance report (GR) for refined analyses as modified by the NRC's safety evaluation report (SER), as well as the refined methodologies suggested by the SER in Appendices III, IV, and VI, to evaluate debris transport to the reactor containment building sump for postulated high energy line breaks requiring sump recirculation (LOCA for CR3). Debris transport is the estimation of the fraction of debris that is transported from debris sources (break location) to the sump strainer. The four major debris transport modes are:

- Blowdown transport is the vertical and horizontal transport of debris to all areas of containment by the break jet.
- Washdown spray transport is the vertical (downward) transport of debris by the containment sprays and break flow.
- Pool fill transport is the horizontal transport of debris by break flow and containment spray flow to areas that may be active or inactive during recirculation.
- Recirculation transport is the horizontal transport of debris from the active portions of the containment floor (recirculation) pool to the sump screen by the flow through the emergency core coolant system (ECCS) and containment spray (CS).

<u>**Blowdown Transport**</u>:

The high energy blowdown following a double-ended guillotine pipe rupture would dislodge only the insulation and coatings in the vicinity of the break location. Blowdown is considered to be omni-directional within lower containment. After pressurizing the D-Ring compartments, the blowdown would primarily relieve upward past the steam generator and reactor coolant pumps to upper containment. Some of the pressure would also be relieved to the area outside the D-Rings through the openings in the bio-shield wall.

During blowdown, it is likely that some small debris would adhere to the walls and equipment around the break. However, due to a lack of quantifiable data on this phenomenon, all debris not ejected upward was conservatively assumed to fall to the floor.

Since the blowdown would relieve to all areas in the containment building, the fraction of blowdown flow to various regions can be reasonably estimated using the relative volumes of containment. Fine debris would be easily suspended and carried by the blowdown flow. Small and large piece debris would 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. Since the openings to the upper containment are directly above the postulated break location, some small and large pieces of debris would be blown into the upper containment.

All debris not blown into the upper containment was conservatively assumed to fall or be washed back to the floor.

The table below shows the transport fractions for each type/size of debris to the upper containment due to the blowdown forces for breaks inside the bio-shield wall. Note that since the latent debris and coatings outside the ZOI are not directly affected by the break jet, none of this debris would be blown to the upper containment.

Blowdown Transport Fractions of Debris to the Upper Containment

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	44%	15%	NA
NUKON™	69%	51%	15%	NA
Qualified Plasite 9028 MI Coatings (inside ZOI)	69%	NA	NA	NA
Qualified Plasite 9009 Coatings (inside ZOI)	69%	NA	NA	NA
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	69%	NA	NA	NA
Unqualified Coatings (outside ZOI)	NA	0%	NA	NA
Degraded Plasite 9028 MI Coatings (outside ZOI)	NA	0%	NA	NA
Degraded Plasite 9009 Coatings (outside ZOI)	NA	0%	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

__Washdown Transport__:

During the washdown phase, debris in the upper containment could be washed down by containment sprays. It was conservatively assumed that all of the debris in the upper containment would be washed back to the lower containment, with the exception of debris held up on grating.

Since the debris blown upward would be scattered in the upper containment, the washdown for this debris can be reasonably determined based on the spray flow distribution. As shown in Section 4.8.3 of the analysis, the washdown flow split is estimated to be 7% to each of the D-Rings, 2% to the equipment hatch, 12% to the refueling canal, 44% to the scupper penetrations, and 28% to the stairwells. As discussed in Section 4.4 of the analysis, debris falling back into the D-Rings would have to pass through grating covering approximately 55% of the north D-Ring, and 30% of the south D-Ring; debris washed through the equipment hatch would have to pass through grating at the intermediate floor elevation; debris washed down in the refueling canal would have to pass through the trash rack and the refueling canal drain; debris washed through the penetrations would not have to pass through any grating; and debris washed down the stairwells would be held up similar to two elevations of grating since each piece of debris would have to be washed through at least two stairwells before being washed to the containment pool.

Washdown Transport Fractions of Debris from Upper Containment through the D-rings

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	12%	8%	NA
Nukon™	14%	11%	8%	NA
Mineral Wool	14%	11%	8%	NA
Qualified Plasite 9028 MI Coatings (inside ZOI)	14%	NA	NA	NA
Qualified Plasite 9009 Coatings (inside ZOI)	14%	NA	NA	NA
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	14%	NA	NA	NA
Unqualified Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9028 MI Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9009 Coatings (outside ZOI)	NA	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Washdown Transport Fractions of Debris from Upper Containment through the Equipment Hatch

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	1%	0%	NA
Nukon™	2%	1%	0%	NA
Mineral Wool	2%	1%	0%	NA
Qualified Plasite 9028 MI Coatings (inside ZOI)	2%	NA	NA	NA
Qualified Plasite 9009 Coatings (inside ZOI)	2%	NA	NA	NA
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	2%	NA	NA	NA
Unqualified Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9028 MI Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9009 Coatings (outside ZOI)	NA	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Washdown Transport Fractions of Debris from Upper Containment to the Refueling Canal Drain

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	12%	12%	NA
Nukon™	12%	12%	12%	NA
Mineral Wool	12%	12%	12%	NA
Qualified Plasite 9028 MI Coatings (inside ZOI)	12%	NA	NA	NA
Qualified Plasite 9009 Coatings (inside ZOI)	12%	NA	NA	NA
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	12%	NA	NA	NA
Unqualified Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9028 MI Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9009 Coatings (outside ZOI)	NA	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Washdown Transport Fractions of Debris from Upper Containment through the Penetrations

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	44%	44%	NA
Nukon™	44%	44%	44%	NA
Mineral Wool	44%	44%	44%	NA
Qualified Plasite 9028 MI Coatings (inside ZOI)	44%	NA	NA	NA
Qualified Plasite 9009 Coatings (inside ZOI)	44%	NA	NA	NA
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	44%	NA	NA	NA
Unqualified Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9028 MI Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9009 Coatings (outside ZOI)	NA	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Washdown Transport Fractions of Debris from Upper Containment through the Stairwells

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	14%	0%	NA
Nukon™	28%	7%	0%	NA
Mineral Wool	28%	7%	0%	NA
Qualified Plasite 9028 MI Coatings (inside ZOI)	28%	NA	NA	NA
Qualified Plasite 9009 Coatings (inside ZOI)	28%	NA	NA	NA
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	28%	NA	NA	NA
Unqualified Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9028 MI Coatings (outside ZOI)	NA	NA	NA	NA
Degraded Plasite 9009 Coatings (outside ZOI)	NA	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Pool Fill Transport:

During pool fill-up, the flow of water would transport insulation debris from the break location to all areas of the recirculation pool. Some of the debris could be transported to inactive areas of the pool. Some of the debris could also be transported directly to the sump screen as the 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 a given cavity can be calculated. (Note that the assumption that debris washdown occurs after inactive cavities have been filled is consistent with the requirements of the SER Section 3.8.)

As water pours onto the containment floor, it would initially flow in shallow, high velocity sheets. This sheeting action would cause both small and large pieces of insulation debris (that may not transport easily during recirculation flow) to be scattered around the containment floor. The D-Ring walls (bio-shield walls) are constructed with no openings at grade level. The personnel access opening is 7 inches above grade and the outlet scupper openings are 12 inches above grade, optimizing entrapment of debris inside the D-Rings. External to the D-Rings a 15 inches high debris interceptor has been installed full width of the floor between the personnel access door and the sump. This interceptor also enhances debris entrapment during pool fill-up. As the water level rises, debris that bypasses the curbs and interceptor would preferentially be swept to cavities below the containment floor elevation, such as the reactor instrument tunnel and the emergency sump.

Since the curb around the sump would stop sunken debris from washing over during the fill-up phase (only a thin sheet of water would be flowing over the top of the curb as the cavity fills), the pool fill-up transport fraction to the sump was only applied for the fine debris that is likely to be suspended. After the sump cavity has filled, there would be no preferential direction to the pool flow until recirculation is initiated.

The table below shows the fraction of debris that would transport directly to the sump screen during pool fill-up. Note that unqualified coatings outside the paint ZOI are assumed to fail after pool fill-up has occurred, so the transport fraction for this debris during fill-up is 0%.

Pool Fill-up Transport Fractions of Debris to Sump Screen

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	0%	0%	NA
NUKON™	32%	0%	0%	NA
Qualified Plasite 9028 MI Coatings (inside ZOI)	32%	NA	NA	NA
Qualified Plasite 9009 Coatings (inside ZOI)	32%	NA	NA	NA
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	32%	NA	NA	NA
Unqualified Coatings (outside ZOI)	NA	0%	NA	NA
Degraded Plasite 9028 MI Coatings (outside ZOI)	NA	0%	NA	NA
Degraded Plasite 9009 Coatings (outside ZOI)	NA	0%	NA	NA
Dirt/Dust	32%	NA	NA	NA
Latent Fiber	32%	NA	NA	NA

Recirculation Transport:

Since the various types and sizes of debris transport differently during the blowdown, washdown, and pool fill-up phases, the initial distribution of this debris at the start of recirculation could vary widely. Insulation debris on the pool floor would be scattered around by the break flow as the pool fills, and debris in upper containment would be washed down at various locations by the spray flow. Due to the fact that the containment pool does not flow preferentially in any given direction after the inactive and sump cavities have been filled and before recirculation begins, it was assumed that the debris washed down by containment sprays would remain in the general vicinity of the washdown locations until recirculation starts.

Latent Debris

With the exception of latent debris washed to the sump or to inactive cavities during pool fill-up, it was assumed that all of the latent debris in containment (dirt/dust and fibers) would be uniformly distributed on the containment floor at the beginning of recirculation. Although a significant quantity of the total latent debris would be in the upper containment and trapped on equipment and structures above the pool level, entrapped by D-Ring curbing and/or the interceptor, additional information on the exact location of the latent debris would be required to take credit for a less conservative distribution.

Unqualified Coatings

The unqualified coatings at CR3 include lead and some unknown coatings assumed to be epoxy that are scattered around in various locations in both upper and lower containment, as well as high temperature aluminum coatings beneath the insulation on the RCS piping, pumps, steam generators, and pressurizer. Given the scattered distribution of the coatings outside the ZOI, it was assumed that these coatings would be uniformly distributed in the recirculation pool. The unqualified aluminum coatings are inside the ZOI, and therefore are treated similar to the other fine debris generated by the LOCA jet.

Degraded Qualified Coatings

Some of the qualified coatings on the walls inside the D-Rings have degraded and are assumed to fail in the debris generation calculation. Since these coatings are inside the D-Rings, it is assumed that the initial distribution would be uniform inside the D-Rings.

Fine Debris

With the exception of debris washed directly to the sump screen or to inactive areas, it was assumed that the fine debris in lower containment at the end of the blowdown would be uniformly distributed in the pool at the beginning of recirculation. The fine debris washed down from the upper containment was assumed to be in the vicinity of the locations where spray water would reach the pool.

Small and Large Piece Debris

Small and large pieces of insulation debris (RMI, Mineral Wool, and NUKON™) not blown to the upper containment were conservatively assumed to be uniformly distributed between the locations where it would be destroyed and the debris interceptor. This is a reasonable assumption since debris generated inside the D-Rings would not be easily blown past the interceptor, and sunken debris transported by the shallow pool fill-up flow would be stopped by the interceptor. The debris washed down from the upper containment was assumed to be distributed in the same locations as the fine debris.

Erosion of Small and Large Debris

Some types of debris could erode when subjected to the continuing forces of break or spray flows and pool turbulence during recirculation. Stainless steel RMI is assumed not to break down into smaller pieces following the initial generation at the beginning of the LOCA. Thus, the only insulation debris types with the potential for erosion are the NUKON and mineral wool (Note: no mineral wool will remain in the LBLOCA ZOI following RFO-16 [Fall 2009]). Appendix III of the NRC SE recommends using a value of 90% debris-eroded value for both small- and large-piece debris to ensure conservatism in the overall transport results. The SE notes that this number can possibly be reduced once better erosion data are available.

Tests performed as a part of the drywell debris transport study (DDTS) have indicated that the erosion of fibrous debris is significantly different for debris directly impacted by containment sprays versus debris directly impacted by break flow. The erosion of large pieces of fibrous debris by containment sprays was found to be less than 1%, whereas the erosion due to the break flow was much higher. Due to differences in the design of Pressurized Water Reactors (PWR) nuclear plants compared to the boiling water reactor (BWR) nuclear plants, the results of the erosion testing in the DDTS are only partially applicable. In a BWR plant, a LOCA accident would generate debris that would be held up below the break location on grating above the suppression pool. In PWR plants like CR3, however, the break would generate debris that would either be blown to upper containment or blown to the floor where the pool would form. Most of the debris would not be hung up directly below the break flow where it would undergo the high erosion rates suggested by the DDTS. Any debris blown to upper containment that is not washed back down, however, would be subject to erosion by the sprays. Based on the results of the DDTS testing, a 1% erosion factor was applied for small and large piece fibrous debris held up in upper containment. This is consistent with the approach taken for the pilot plant in the SER (Appendix VI) (Reference 3). The erosion mechanism for debris in the pool is somewhat different than what was tested in the DDTS. To determine the erosion fractions for debris that settles out in the recirculation pool, testing was performed using both small and large pieces of fiberglass debris (Reference 65). To quantify the recirculation pool erosion fractions for CR3, 30 day erosion testing was performed. Based on this testing, an erosion fraction of 10% was used for the small and large pieces of fiberglass debris in the recirculation pool that do not transport to the sump.

CFD Model of Containment Recirculation Pool

CR3 applied the debris transport refinement discussed in Section 4.2.4.2 of NEI 04-07, as modified in Section 4.2.4 of the NRC SE on NEI 04-07, which allows the use of Computational Fluid Dynamics (CFD) software. Using this approach, the transport of debris to the reactor containment building sump associated with the governing high energy pipe break for each type of debris generated was evaluated.

FLOW-3D was used to perform the flow field calculations for CR3. Iterative CFD model runs were performed to optimize the physical design features and placement of both a flow distributor and a debris interceptor. Once the characteristics of these devices were determined, the individual debris types were also input.

The recirculation pool debris transport fractions were determined through CFD modeling. To accomplish this, the CAD model STL files were 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 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 values (i.e., the minimum velocity or turbulence required to transport a particular type/size of debris), the total transport of each type/size of debris to the sump screens can be determined. This section describes the details of the CFD modeling.

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 4 inches tall in order to closely resolve the vicinity of settled debris. To further define specific objects, node planes were placed at the top of key structures including the scuppers in the bio-shield wall and the curb around the sump. A nested mesh was placed around the flow diverter outside the D-Ring wall in order to properly resolve the location of the diverter. The total cell count in the model was 629,760, a satisfactory compromise between model run-time and model resolution.

The following table summarizes the metrics used in estimating debris transport in the CR3 containment pool:

Debris Transport Metrics

Debris Type	Size	Terminal Settling Velocity (ft/s)	Reference	Calculated Minimum Turbulent Kinetic Energy (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	NUREG/CR-6772 Table 3.5	0.21	0.28	NUREG/CR-6772 Table 3.5
	Large Pieces (>4")	0.48	NUREG/CR-6772 Table 3.5	0.35	0.28	NUREG/CR-6772 Table 3.5
NUKON™	Individual Fibers	0.0074	NUREG/CR-6808, Fig. 5-2	8.2E-05	NA	-
	Small Pieces (<6")	0.15	NUREG/CR-6772, Table 3.1	3.4E-02	0.12	NUREG/CR-6772 Table 3.2
	Large Pieces (>6")	0.41	NUREG/CR-6772, Table 3.1	0.25	0.37	NUREG/CR-6808, Table 5-3
Mineral Wool	Individual Fibers	Assumed to be the same as NUKON™		Assumed to be the same as NUKON™		-
	Small Pieces (<6")	Assumed to be the same as NUKON™		Assumed to be the same as NUKON™		-
	Large Pieces (>6")	Assumed to be the same as NUKON™		Assumed to be the same as NUKON™	0.9	NUREG/CR-6808, Table 5-3
Paint Debris	10-micron particulate (120 lbm/ft3)	3.0E-04	Calculated per Stokes' law	1.3E-07	NA	-
	10-micron particulate (96 lbm/ft3)	1.8E-04	Calculated per Stokes' law	4.6E-08	NA	-
	10-micron particulate (90 lbm/ft3)	1.5E-04	Calculated per Stokes' law	3.2E-08	NA	-
	10-micron particulate (94 lbm/ft3)	1.7E-04	Calculated per Stokes' law	4.1E-08	NA	-
	Epoxy paint chips	0.13	NUREG/CR-6916	2.5E-02	0.27	NUREG/CR-6916
Dirt/Dust	17.3-micron particulate (169 lbm/ft3)	1.65E-03	Calculated per Stokes' law	4.1E-06	NA	-

Note: The transport fractions for individual latent fibers and for dirt/dust particulate is 100%, i.e., the settling of fine debris is not assumed to occur and no credit is taken for settling of fines.

Flow Distributor and Debris Interceptor Form and Function

As part of the ECCS strainer replacement effort at CR3, a flow distributor and a debris interceptor have been installed. The flow distributor and debris interceptor have been fashioned to promote settling and capture of specific types of LOCA-generated debris away from the emergency sump without impeding the flow of water to the sump.

The function of the distributor is to spread the flow of water from the D-Ring doorway out over the available surface area on the west central floor of containment. Without the flow distributor, the flow from the doorway would channel along the D-Ring wall with relatively high velocity and turbulence. The benefit of spreading the flow out over the floor is increased debris settling. The function of the debris interceptor is to trap debris tumbling along the containment floor towards the emergency sump. The height of the debris interceptor (15 inch) is significantly less than the predicted depth of the containment pool (24 inch) such that if the perforated plate of the interceptor were to become blocked with debris, it could not impede the flow of water to the sump.

The flow distributor and debris interceptor have been specifically designed to promote the settling/capture of 5-mil degraded epoxy paint chips. A suitable design was arrived at based on the results of several CFD calculations investigating different extents of the distributor, different sizes of the slot in the distributor, and different placements of the interceptor. While placing the interceptor closer to the sump seems prudent, elevated turbulence near the sump would defeat the interceptor since paint chips would simply be carried over it. The debris interceptor is capable of retaining 96 ft^3 of debris from continuing to the sump (40.5 ft^3 is actually captured as identified in the table below).

CONCLUSIONS

Based on the results of the transport analysis, the following conclusions can be drawn for debris transport in the CR3 containment building:

- The blowdown following an LBLOCA would carry a large fraction of fine and small piece debris into upper containment. A small fraction of large piece debris would also be carried into the upper containment.

- Given the large spray flow, the majority of transportable debris in the path of the spray drainage would be washed to the lower containment. However, a significant quantity of the small and large pieces of debris would be held up on grating. Some of the debris would also be held up in the refueling canal or washed to the inactive reactor cavity.

- Some debris could be transported directly to the ECCS sump screens during pool fill-up. However, the curb around the sump would stop sunken debris from transporting into the sump during fill-up.

- The CFD results show that a large fraction of sunken debris would be transported to the debris interceptor, but the interceptor would prevent up to 96 ft^3 of this debris from transporting to the sump. Therefore, the only transport of debris to the sump would be fine debris, debris washed down beyond the interceptor, and unqualified coatings failing downstream of the interceptor.

Debris Transport Analysis Results

Debris transport logic trees were developed for each type of debris generated for CR3. The logic trees were used to determine the total fraction of debris that would reach the sump strainer for the governing high energy line break location. The results are summarized in tabular form below:

Overall Fraction of Debris Transported to and Captured By Debris Interceptor (LBLOCA)

Debris Type	Size Transport	Fraction	Quantity to Interceptor
Stainless Steel RMI	Small Pieces (<4")	29%	22.6 ft^3
	Large Pieces (>4")	30%	9.6 ft^3
NUKON™	Individual Fibers	0%	0.0 ft^3
	Small Pieces (<6")	44%	3.5 ft^3
	Large Pieces (>6")	7%	0.0 ft^3
Qualified Plasite 9028 MI Coatings (inside ZOI)	Fines	0%	0.0 lb
Qualified Plasite 9009 Coatings (inside ZOI)	Fines	0%	0.0 lb
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	Fines	0%	0.0 lb
Unqualified Coatings (outside ZOI)	Chips	32%	0.2 ft^3
Degraded Plasite 9028 MI Coatings (outside ZOI)	Chips	39%	2.3 ft^3
Degraded Plasite 9009 Coatings (outside ZOI)	Chips	39%	2.3 ft^3
Dirt/Dust	Fines	0%	0.0 lb
Latent Fiber	Individual Fibers	0%	0.0 lb
Total Debris			**40.5 ft^3**

Overall Fraction of Debris Transported to the Sump (LBLOCA)

Debris Type	Size Transport	Fraction	Quantity @ Strainer
Stainless Steel RMI	Small Pieces (<4")	11%	12.2 ft^3
	Large Pieces (>4")	3%	2.5 ft^3
NUKON™	Fines	92%	1.84 ft^3
	Small Pieces (<6")	20%	1.6 ft^3
	Large Pieces (>6")	12%	0.0 ft^3
Qualified Plasite 9028 MI Coatings (inside ZOI)	Fines	92%	132.9 lb (1.11 ft^3)
Qualified Plasite 9009 Coatings (inside ZOI)	Fines	92%	106.4 lb (1.11 ft^3)
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	Fines	92%	7.7 lb (0.03 ft^3)
Unqualified Coatings (outside ZOI)	Chips	18%	8.5 lb (0.1 ft^3)
Degraded Plasite 9028 MI Coatings (outside ZOI)	Chips	0%	0.0 ft^3
Degraded Plasite 9009 Coatings (outside ZOI)	Chips	0%	0.0 ft^3
Dirt/Dust	Fines	100%	170 lb (1 ft^3)
Latent Fiber	Individual Fibers	100%	30 lb (12.5 ft^3)
Total Debris			**34 ft^3**

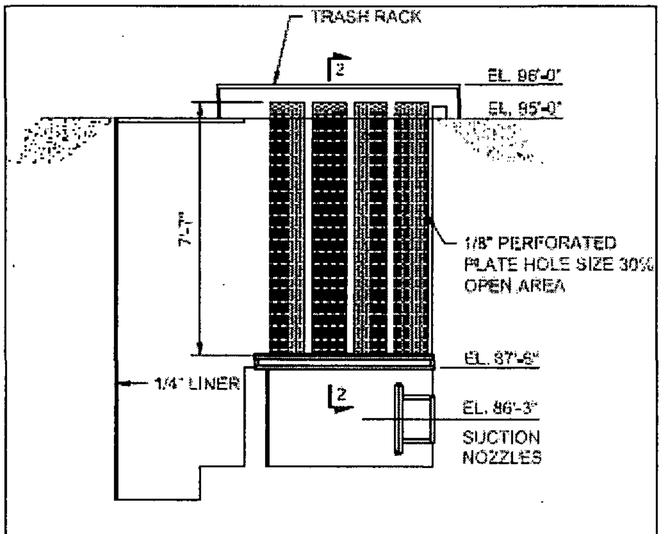
f. Head Loss and Vortexing

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 (CS).***
- ***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.***

Supplements previous information:

- Piping and Equipment schematics of the ECCS and CS systems are included as Attachment 1. A cross-sectional elevation view of the CR3 sump/strainer arrangement follows:



SECTION 1-1

- Submergence

The minimum strainer submergence under SBLOCA and LBLOCA conditions is:

SBLOCA:	96.84 (Ref 15) – 95.37 = 1.47 feet
LBLOCA:	97.04 (Ref 15) – 95.37 = 1.67 feet

The new CR3 sump strainer was installed during RFO-14 (November 2005). The post-LBLOCA water level at the onset of recirculation has been determined to be between plant datum elevations 97.04 feet (96.84 feet for SBLOCA) and 101.90 feet (Reference 15). The containment floor elevation is 95.00 feet nominal, therefore the post-LOCA pool water level is expected to be between approximately 2 feet and 7 feet deep, based on the amount of BWST depletion and on the amount of water inventory holdup in other containment compartments. The highest point of the sump strainer is plant elevation 95.37 feet (Reference 11), which represents a strainer LBLOCA submergence depth of at least 1 foot 8 inches (1 foot 5 inches for SBLOCA). The 32 top hat strainers are each 7 foot 6 inch tall, vertically mounted in the sump at elevation 87.87 foot. The two 14 inch Net Positive Suction (NPS) ECCS pump suction nozzles are horizontal outlet runs near the bottom of the sump, with a centerline elevation of 86 feet 3 inch which corresponds to a submergence of at least 10.2 feet deep (L/D ~ 10).

The immediate strainer footprint (plan view) is protected by a horizontal trash rack made of 1-1/2 inch x 4 inch standard floor grating with an upper surface elevation of 96.00 feet, which is 1 foot above the containment floor elevation (a portion of the trash rack away from the strainer assembly is at elevation 95.00 feet). Therefore, the trash rack has at least 1 foot of submergence during LOCA re-circulation. Since the entire strainer and trash rack assembly is completely submerged and since ECCS flow is essentially vertically downward, the bulk post-LOCA surface water velocity down into the strainer area is independent of the local strainer horizontal entrance velocity at any given point along the strainer height. However, the strainer configuration and trash rack assembly have been analyzed for air core vortex suppression capability and it has been concluded that the ECCS pumps and their suction piping are not susceptible to air ingestion due to surface water vortex formation:

- Vortexing

The CR3 containment sump arrangement was evaluated for the potential of vortex formation. Calculation M90-0021, Attachment 31 (Reference 14), provides the assessment which used multiple approaches and references as bases. First, based on methodology provided by Y.R. Reddy and J.A. Pickford, which evaluates outlet line velocity, pipe diameter, and outlet line submergence depth, the horizontally mounted sump outlet lines are not susceptible to drawing a vortex from the containment pool water surface, irrespective of any intervening grating and strainer assemblies. Conversely, based on guidance provided by NUREG-0897 and Regulatory Guide 1.82, Revision 3, the sump outlet piping could be susceptible to air core vortex formation if a vortex suppressor is not installed, due to pipe velocity and Froude no. based on submergence. However, CR3 has horizontal grating installed as a trash rack over the entire sump footprint, and it is completely submerged prior to post-LOCA recirculation initiation. This is an excellent vortex breaker configuration, similar to the non-cubic design configuration discussed in Regulatory Guide 1.82. CR3 also has 32 vertically mounted top hat strainer assemblies arranged in an 8 x 4 array. These strainers are constructed of perforated plate formed into cylinders, each with crucifix forms at the strainer outlet to the sump. The convoluted combination of the trash rack, its support structure, the strainer arrangement, and strainer design eliminates the potential for air core vortices from reaching the sump outlet piping, regardless whether a surface swirl above the sump develops or not.

Since the upper portion of the sump strainer is at least 1.47 feet below the post-LOCA water surface and because surface water vortices cannot occur due to the sump strainer and trash rack vortex breaking configurations, direct air ingestion through the strainer due to buoyant debris collection on the strainer is not possible (i.e., floating debris cannot be drawn down to the strainer surface by a vortex swirl). Additionally, the maximum strainer head loss due to postulated post-LOCA debris accumulation is predicted to be less than 0.10 feet of water column (Reference 69). Since the maximum head loss across the strainer is less than the submergence head, production of water vapor or gas evolution across the strainer due to the strainer pressure drop is not expected to occur, even when pumping saturated water.

- Head Loss Testing

(Evaluation results are based on preliminary test report.)
CR3 performed prototypical head loss testing with chemical precipitates at the Alion Science and Technology test facility in Warrenville, Illinois. The tested configuration consisted of 9 single "top hat" strainers arranged in a 3 x 3 array. Each test top hat was 38 inch in length, compared to 90 inch for the actual installed top hats, due to size limitations within the test tank. The screen opening size (1/8 inch) and top hat diameter (12 inch OD and 8 inch ID) were consistent with the installed top hats. The strainer test assembly was surrounded on all sides by panels designed to simulate sump pit walls.

The flow rate through the test assembly was established to obtain the CR3 strainer design approach velocity (0.0185 ft/s). The water was returned to the test tank through a horizontal sparger that discharged at the tank bottom, precluding settling of debris on the tank floor. The testing was performed with tap water at approximately 90°F.

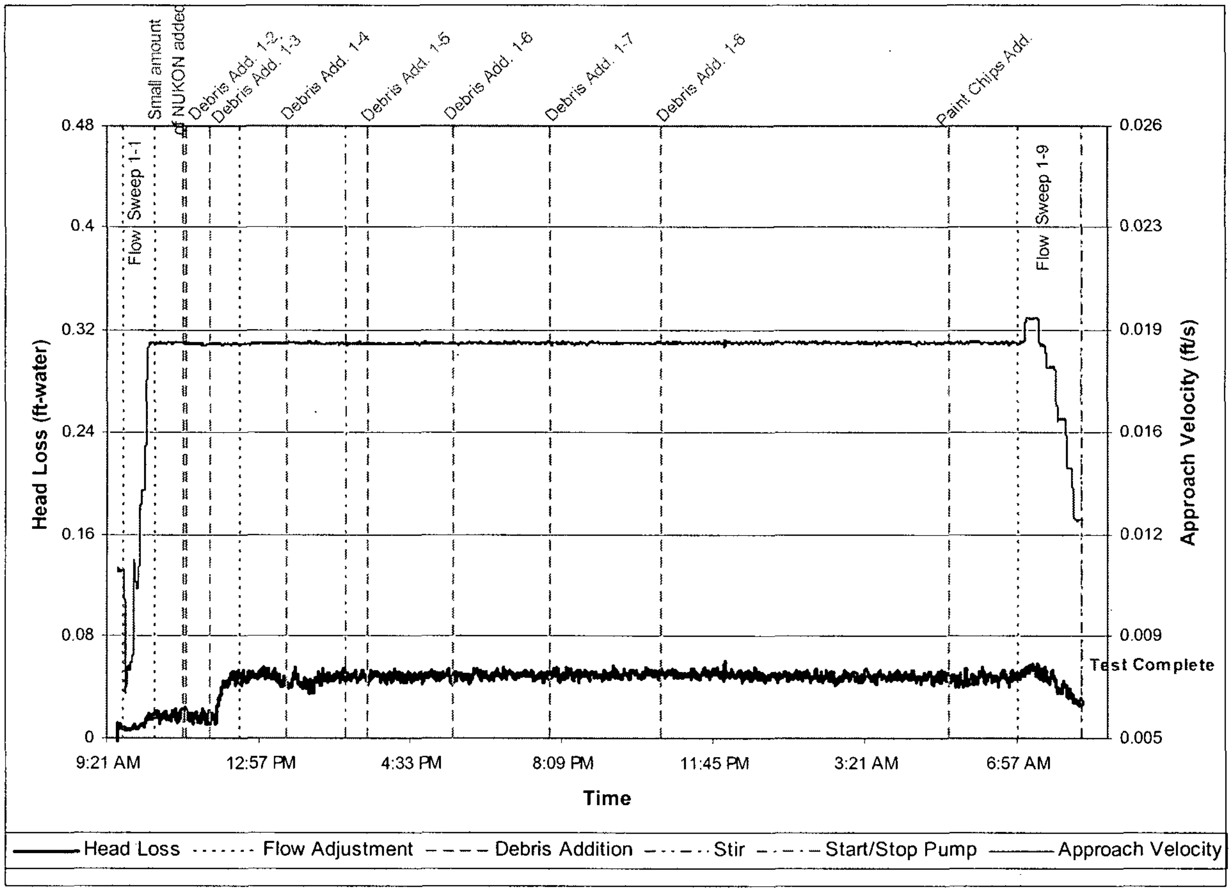
The debris reaching the CR3 sump strainer consists of RMI, NUKON insulation, qualified and unqualified coatings, and latent dirt/dust and fiber. The head loss associated with RMI was calculated in accordance with equation 3.7.2-9 of the GR and determined to be negligible (<<0.01 ft), and was therefore not included in the prototypical head loss testing. NUKON insulation was used in the test for both the insulation as well as latent fiber, ground silica was used as a surrogate for coatings particulate, and silica sand was used as a surrogate for latent dirt/dust. In addition, paint chips (1/8 inch minimum size) were used to represent unqualified coatings as discussed below.

The chemical precipitates were prepared in accordance with the methodology of WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," Revision 0. The chemical precipitate loads were based on the 30-day result of the spreadsheet developed for the WCAP. Since CR3 utilizes trisodium phosphate (TSP) as the buffering agent, the spreadsheet was modified to credit phosphate inhibition of aluminum corrosion in accordance with WCAP-16785-NP, Revision 0. See Section 3.o for further discussion of chemical precipitates and testing.

A scaling factor equal to the ratio of the test strainer surface area (132.33 ft^2) to the CR3 strainer surface area (1050 ft^2)[3] was used to determine the quantity of debris and chemical precipitates for the test. The scaling factor (0.126) was applied to the quantity of debris calculated to transport to the sump, as well as to the quantity of chemical precipitates determined from WCAP-16530-NP.

The test was conducted by first adding the particulates, followed by the fiber debris. Due to the potential for a clean screen area, paint chips were then added for the unqualified coatings (in addition to an equivalent amount of unqualified coatings included in the particulate load). Chemical precipitates were then added as a batch of calcium phosphate, two batches of sodium aluminum silicate and aluminum oxyhydroxide, and a final batch of aluminum oxyhydroxide. Finally, paint chips equivalent to an additional 600 ft^2 of unqualified or degraded qualified coatings (100% transport to the sump) were added for additional conservatism. Head loss was allowed to stabilize between each addition of material to the tank, as well as following the final addition of chemicals.

The final head loss after system stabilization was <0.10 ft.



Head Loss Test Graph

- Interstitial Volume

The CR3 strainer has an interstitial volume of 231.9 ft^3. This is significantly greater than the 34 ft^3 of debris that reaches the sump. Therefore, there is adequate volume available to accommodate the maximum volume of debris predicted to arrive at the sump screen.

- Thin Bed

[3] A strainer surface area is of 1050 ft^2 is based on 1139 ft^2 overall area minus 89 ft^2 reserved for labels, tags, etc.

For the CR3 strainer array, the volume of fiber required to theoretically form a 1/8 inch fiber bed (the thickness of a "thin bed") is 11.9 ft^3. This quantity is based on the assumption that the fibrous debris forms a perfectly homogeneous bed on a flat plate equivalent surface area. The strainer array at CR3 is an advanced strainer that was intentionally designed to collect debris non-uniformly. Furthermore, the strainer array is located in a recessed pit with the majority of the array lower than the basement floor, which enhances non-uniform debris accumulation as the debris will tend to settle out and preferentially collect on the lower portions of the array. Experience with enhanced strainer designs as reported in NUREG/CR-6808 suggests that the bed formation for appreciable head loss of fiber and particulate debris occurs only at multiple values of the fiber debris loads needed to form a theoretically homogeneous debris bed 1/8 inch thick. Based on these considerations, the analyses assume that at least 3 times the quantity of fibrous debris required to form a theoretical 1/8 inch debris bed on the CR3 strainer array is required before a sufficient debris bed is formed to produce a noticeable head loss, i.e., at least 35.7 ft^3 of fibrous material needs to arrive at the strainer for a noticeable head loss to occur.

The assumption that a thin bed is not formed with the fiber volume required to form a uniform 1/8 inch fiber bed is supported by prototypical head loss testing, which demonstrated that a clean screen exists with an equivalent total fiber volume of approximately 16 ft^3. This conclusion was visually confirmed during subsequent additional head loss testing.

- Design Maximum Head Loss

The predicted maximum head loss during the design of the new strainers was based on calculations utilizing the NUREG/CR-6224 correlation and the debris source term that existed at the time (i.e., a significant quantity of mineral wool). The predicted head loss was increased by a factor of 1.5 to account for uncertainties such as chemical effects, and the results were then tripled for additional conservatism. This resulted in a design differential pressure of 1.5 psid (3.6 ft).

- Margins

The head loss calculation uses the actual head loss from the Chemical Effects head loss test, which demonstrated an actual head loss of <0.10 ft versus the design head loss of 3.6 ft. The head loss is based on a conservative total flow rate (8696 gpm versus 8508 gpm maximum), and simultaneous arrival of chemical precipitates concurrent with maximum sump flow (i.e., no credit is taken for timing of precipitate formation and potential securing of HPI and CS pumps).

- Clean Strainer Head Loss

To determine the clean strainer head loss (CSHL), the pressure drop was first calculated across the perforated plate strainer surface, assuming uniform flow distribution. The resulting pressure drop is negligible and not used in the CSHL calculation. Instead, the head loss was determined as follows:

- o The total flow (8696 gpm) was assumed to be equally divided among 30 top hats. The remaining 2 top hats with inspection ports were conservatively not included.
- o Flow was assumed to enter at the top of the top hat and travel through the annulus for the entire length of the top hat. This is conservative, as it increases the velocity of the fluid throughout the top hat.
- o The head loss consists of the friction loss due to the inner walls of the top hats, the inner support members, and the exit at the bottom of the top hats

The resulting clean strainer head loss is 0.083 ft at 8696 gpm.

The major assumptions in the CSHL calculation include:

- o The flow rate was assumed to be 8696 gpm. The actual maximum error-corrected recirculation flow rate is 8508 gpm. This includes two LPI pumps, two HPI pumps, and 2 BS pumps.
- o As stated above, only the top hats with an outer and inner perforated plate wall were assumed to carry flow. This increases flow, and therefore velocity, in each or the remaining 30 top hats.

- The minimum fluid temperature was assumed to be 120°F. By the time the recirculation fluid reaches this temperature, the flow would be reduced due to securing of BS pumps and some ECCS pumps. The impact of lower flow rates would be more significant than the impact of lower fluid temperatures.

- Debris Head Loss Methodology

  The steps for determining head loss across the debris-laden sump strainer were as follows:

  1. Debris identification (Reference 17)
  2. Debris generation (Reference 17 and 59)
  3. Debris transport (Reference 18)
  4. Debris head loss (Reference 20)

  The types of debris identified in CR3 containment, and determined to transport to the RB sump, are discussed in other sections of the supplemental response and will not be repeated here. The debris head loss analysis is based on the empirically derived head loss from the chemical effects head loss test discussed above. See "Head Loss Testing" above for discussion of test methodology and assumptions.

- Submergence/Venting

  As stated previously, the sump and sump trash rack are completely submerged prior to the onset of post-LOCA sump recirculation. Each top hat strainer segment has a vent hole in the upper closure plate that allows all remaining air to escape as the containment fills with water during the injection phase from the BWST. Since there is no trapped air in the strainer control volume, a water seal is formed across the entire strainer surface.

  The only penetration through the strainer control surface is a sealed capillary sensing tube that is the high pressure leg of a differential pressure transmitter that serves as a sump water level indicator and as a strainer pressure drop indicator (References 11 and 12). Since the line is completely filled with fluid and sealed, it cannot provide a physical air passage between the containment atmosphere and the control volume on the downstream side of the sump strainer. Other than the sump ECCS/CS outlet lines, this is the only penetration across the strainer surface and therefore no vent path exists.

- Settling

  CR3 does not credit near-field settling for head loss purposes.

- Temperature/Viscosity Scaling

  Although the test was performed with much cooler water temperature compared to actual plant conditions, no scaling of the results was performed. This is conservative, as the higher sump temperature would have a lower viscosity, and therefore lower head loss across the strainer.

- Accident Pressure

  Containment accident pressure was not credited in evaluating whether flashing would occur across the strainer surface (Reference 11).

g. Net Positive Suction Head (NPSH)

The objective of the NPSH section is to calculate the NPSH margin for the ECCS and CS 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 CS 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.***

Revises previous information:

- Flow Rates, Temperature, Water Level

  During the recirculation phase, the LPI and CS pumps take suction from the RB sump. In addition to the flow injected into the RCS, the LPI pump flow also includes 100 gpm of minimum flow recirculation and 580 gpm of HPI flow (piggyback operation):

ECCS and CS Pump Recirculation Phase Flow (Reference 14)

Pump	Design Flow (gpm)	Instrument Error (gpm)	Min Flow Recirculation[4] (gpm)	HPI Flow (piggyback) (gpm)	Total (gpm)
LPI (DH)	2000	312	100	580	2992
CS	1200	162	n/a	n/a	1362

The total recirculation sump flow rate is 8508 gpm with two operating trains. A bounding flow rate of 8696 gpm is used for testing and head loss analyses.

[4] The DH pumps include a minimum flow recirculation line that is accounted for in the total pump flow calculation. Flow through this line is in addition to the sump flow rate.

The peak post-accident sump temperature is approximately 253°F prior to transfer to the recirculation phase, and approximately 243°F following transfer (Reference 60).

The minimum containment water level used for determining $NPSH_a$ is 96.92 ft for SBLOCAs, and 97.12 ft for LBLOCAs (Reference 15). [Note: these elevations differ slightly from the strainer submergence elevations given in section 3.f. This is due to differences in assumed containment temperatures. The minimum submergence elevations are based on temperatures that maximize atmospheric holdup, while the NPSH elevations are based on temperatures that minimize $NPSH_a$].

- Calculation Assumptions

Pump flow rates are based on worst-case error corrected values (HPI pumps are assumed to be at run-out conditions).

Termination criteria exists that would allow shutting down both HPI pumps prior to transferring to sump recirculation (Reference 61). Since meeting the termination criteria cannot be guaranteed in all scenarios, the total recirculation flow rate is based on 2 full trains operating at maximum flow conditions.

The peak recirculation sump temperature is based on one train of ECCS, one train of BS, and one RB fan cooler in operation. This minimizes heat removal from the RCS and containment, maximizing sump temperature.

The containment water level for NPSH calculations is based on a sump temperature of 204.7°F. This temperature is the saturation temperature corresponding to the minimum allowable operating containment pressure of -2.0 psig per ITS 3.6.4 (Reference 62). Using this temperature is conservative, as it results in a higher viscosity and therefore higher pressure drop in the pump suction piping when compared to saturation temperature at atmospheric conditions (212°F @ 14.7 psia).

- Required Net Positive Suction Head ($NPSH_r$) Basis

The LPI pumps apply a 3% head reduction criterion in accordance with industry standards. A 5% head reduction is applied to the BS pumps (Reference 14). The required NPSH criterion was reviewed by the NRC staff as part of the Pilot Plant audit performed in 2005 (Reference 4, Section 3.6.2) and found to be acceptable based on pump materials and the fact that the drop in head with reduced available NPSH is gradual and not a sudden drop (the pump is not operating on the knee of the curve).

- Friction

The NPSH methodology for CR3 pumps has been reviewed and accepted by the Staff (Reference 4, Section 3.6.2). The CR3 NPSH analysis (Reference 14) is performed utilizing the AFT Fathom software program. Friction losses are based on the absolute roughness of clean commercial steel pipe, which is conservative compared to the absolute roughness of the installed stainless steel piping. Flow coefficients for valves are based on Crane Technical Paper No. 410. The methods of D.S. Miller are used to determine the flow losses associated with bends, tees, and the interactions between them. The Staff questioned the use of Miller frictional resistance coefficients for pipe fittings and the impact on NPSH margin when compared to more traditional handbook values, such as those published in Crane or Idlechik literature. A sensitivity case was run using the AFT Fathom hydraulic model in Reference 14, and the results indicated that the head loss margins would be lowered by about 0.4 feet if these handbook values were used in place of the Miller values. CR3 contends the use of Miller is realistic since it is based on empirical data, but noting that the un-credited NPSH margin in Reference 14 far outweighs what may be considered by some to be a non-conservative approach using the Miller coefficients. Examples of un-credited NPSH margin include (Reference 14):

		Additional Margin (ft)
1	The Hydraulic Institute discusses the use of a temperature correction factor to correct $NPSH_r$ at elevated temperatures. At an accident temperature of 204.7°F a temperature correction of 0.7 ft (higher at greater temperatures) could be applied, but is not. This practice is also recognized in NUREG-0897, but is discouraged by NEI 04-07 and the SER by their endorsement of Regulatory Guide 1.82, Rev. 3 (CR3 is not committed to this Regulatory Guide).	0.7
2	The Building Spray Pump (BSP)/Decay Heat Pump (DHP) NPSH calculation design basis condition involves pumping saturated water at combined DH/BS/MU flow rates corresponding to those of a large break LOCA, or at least a large SBLOCA. Lower total flow rates do not challenge the $NPSH_r$ of the pumps due to lower line losses associated with the lower flow. There is no effect due to the increased vapor pressure at higher temperatures, since the RB Sump water is assumed to be at saturated conditions, and therefore the sump liquid over-pressure is the same as the vapor pressure of the water. The sump water temperature away from (below) the surface is expected to be below the corresponding saturation pressure because some heat will transfer out through the bottom of the RB, some stratification, and through the piping on the way to the pumps. The fluid at the pumps is sub-cooled and significant margin is gained. For example, 204.7°F saturated water (-2 psig in RB) sub-cooled to 200°F provides an additional 2.8 feet of NPSH margin, due to a decrease in the fluid vapor pressure, whereas an AFT Fathom model sensitivity run using Case 3 with 200°F water indicates there is negligible head loss impact due to the viscosity/density of the cooler water (relative to the NPSH margin gain provided by vapor pressure reduction).	~2.8
3	Per NRC Safety Guide 1, there can be no credit taken for RB over-pressure due to the increased partial pressure of air at the elevated temperatures that would result during a LOCA. In reality, an increase in containment air temperature from 130°F to 204.7°F would increase the partial air pressure about 1.865 psi which would provide about 4.48 feet of un-credited $NPSH_a$. This margin increases with higher temperatures.	~4.5
4	The approach used in this calculation is to establish conditions that result in the lowest expected flood plain elevations (i.e., SBLOCA, minimum BWST, large hideout inventories, etc.) that would exist simultaneously with maximum sump temperatures, ECCS flow rates, and instrument uncertainties associated with an LBLOCA event. While this combination of parameters is highly improbable, the result provides a high degree of confidence that the entire potential spectrum of break sizes/locations or RB conditions and ECCS flow rate responses are bounded, and will accommodate any hydraulic gradient necessary in the flood plane to provide flow to sump.	Varies (≥0.5)
5	The individual flow setpoint uncertainties for all four pumps (BS/DH) are assumed to establish the highest possible flow rate for each. Portions of these uncertainty values are random errors, therefore the sump screen head loss could be lowered by the "square root of the sum of the squares" method of the random values $(e_{dhp-1a}^2 + e_{dhp-1b}^2 + e_{bsp-1a}^2 + e_{bsp-1b}^2)^{0.5}$ since all four flow setpoints affect this common component, and the common loop suction line losses could also be lowered by SRSS method $(e_{dhp-1a}^2 + e_{bsp-1a}^2)$, since each train shares a run of piping established by two setpoints. This doesn't include an established HPI margin of about <u>20 gpm</u> that is included in the 580 gpm assumption (560 gpm maximum predicted). The estimated total margin due to the dynamic effects associated with these conservative assumptions is about 0.5 feet, primarily due to lower frictional losses in the suction piping.	~0.5

- System Response Scenarios/Pump Operational Status

The CR3 ES systems include two trains of emergency cooling pumps. Each ECCS train consists of one high pressure injection (HPI) pump and one low pressure injection (LPI) pump. Each CS train consists of one spray (CS) pump. Both ECCS and CS trains (up to 6 pumps) are aligned to the borated water storage tank (BWST), and are subsequently aligned to the RB sump by manual operator actions once a pre-determined minimum water level in the BWST has been reached.

System response is determined by break size and resulting reactor coolant system (RCS) and containment pressure characteristics. The HPI pumps and LPI pumps are actuated when RCS pressure decreases to 1625 psig and 500 psig, respectively. A 4 psig containment pressure will also actuate HPI and LPI. Similarly, the CS pumps are actuated when containment pressure increases to 30 psig. Once actuated, automatic flow control valves, physically pre-set in the appropriate throttle position, control LPI flow to 3000 gpm per train. Depending on break size, CS pump actuation may or may not occur. Once actuated, automatic flow control valves control CS flow to 1500 gpm.

For a small break LOCA, the rate of RCS depressurization will be slow and therefore create a delay between HPI and LPI actuations. Due to the relatively low shutoff head of the LPI pumps, LPI flow to the RCS will not begin until the RCS depressurizes to approximately 200 psig. For a large break LOCA, rapid RCS depressurization and concurrent containment pressurization will cause HPI, LPI, and CS actuation early in the event. Since recirculation flow rates are much lower for SBLOCA events, and the water levels are nearly identical, the LBLOCA is bounding for NPSH determination purposes. For the bounding large break LOCA, RCS pressure will be sufficiently low to allow full HPI and LPI, resulting in the most rapid depletion of the BWST, therefore the earliest switchover to RB sump recirculation.

For both small and large break LOCAs, the setpoints for LPI and CS flow control are manually reduced to 2000 gpm and 1200 gpm, respectively, as BWST level decreases to a predetermined level. The HPI pumps (if HPI termination criteria are not satisfied) are aligned to take suction from the discharge of the LPI pumps (piggyback operation). Transfer to RB sump recirculation is then accomplished by opening the RB sump suction valves, then by closing the BWST outlet valves. Both LPI and both CS pumps take suction from a common RB sump. Reference 14, Attachment 32, demonstrates the NPSH margin that is recovered as water temperature drops during recovery with a constant sump flow rate.

- Single Failure Assumptions

The ECCS and CS systems include 100% capacity redundant trains. HPI, LPI and CS pumps are secured manually only if specific termination criteria are met. Therefore, the design basis NPSH analyses assume that all pumps in both trains are operating concurrently throughout the injection and recirculation phases of emergency cooling. Failure of a single pump or complete pump train to operate results in decreased head loss across the common sump screen and reduced frictional losses in the failed component's common piping system. Therefore, these failures have a positive effect on NPSH margin (increased available NPSH).

- Sump Water Level

The minimum water level in containment at the start of transition to recirculation was calculated to be 96.92 ft elevation for a small break LOCA and 97.12 ft for a large break LOCA. The floor of containment is at elevation 95.0 feet; thus, the minimum pool depth is 1.92 ft for a small break LOCA and 2.12 ft for a large break LOCA.

The transition to ECCS recirculation begins when the BWST is drained to the 15 foot level, at which point the calculated 97.12 ft minimum containment water level is reached. Transition to ECCS recirculation is completed prior to the BWST being drained to approximately 7 feet, assuming the RB pressure is low enough to support continued feeding from the BWST and not the sump. Therefore, during transition to recirculation, the water level should increase above the assumed

97.12 ft level; however, no credit is taken for the additional water inventory depleted from the BWST during the transition to recirculation.

The water-level calculation determines the amount of water injected into containment, then accounts for any water inventory that may not reach the sump, i.e., that which may be held up elsewhere in the building. The water level calculation conservatively accounts for the sources of water reaching the containment floor and for the water holdup mechanisms and those associated volumes. Determination of the minimum water level accounted for water holdup in the following locations:

Source	Volume (ft^3)
1. Elevation 160' and 119' Floor Slope (blocked floor drains)	478 + 419 = 897
2. Reactor Cavity >El. 104'	5,117
3. Fuel Transfer Canal	1,524
4. Instrumentation Tunnel < El. 104')	1,951
5. Floor Cut-out @ 94'	258
6. RB Sump Fill-up	1,124
7. BS and DH Dry Pipe Volume	520
8. RC Drain Tank	844
9. 95' Floor Drains	43
10. Core Flood Room	24
11. Condensation on Surfaces	174
12. Pressurizer Steam Space	570
13. RCS Shrinkage	2,943
14. Refueling Crane Rail Space	40
15. RCP Lube Oil Collection System	115
Subtotal:	**16,119**
16. 204.7F Sat. Steam in atmosphere	1,139
17. Containment Spray Mist in atmosphere	127
18. Break flow water in transit to the pool	32
Total:	**$V_{retained}$ = 17,442 ft^3**

The inputs to the water level calculation are biased toward minimizing the containment water level. The calculation uses only the BWST, the volume control tank (MUT), and the CF tanks as water sources. The BWST is assumed to initially be at the ITS low-level and as injection proceeds the level is assumed to drop to manual transition setpoint, at which point the recirculation phase immediately begins, which is conservative.

- Sump Water Level Assumptions

  See "Sump Water Level" section above.

- Volumes Accounted for in Pool Level Calculations

  The sump water level calculation accounts for empty pipe volumes (spray piping, pump suction piping, floor drain piping), water droplets, condensation and holdup on horizontal and vertical surfaces. See "Sump Water Level" section above.

- Displaced water resulting in higher pool level.

  Water reaching the containment floor will be displaced by the following equipment (Reference 15):
  - Waste transfer pumps WDP-2A/2B (0.58 ft^3); these pumps are located in the normal-duty side of the RB sump.
  - RC drain tank transfer pumps WDP-7 (3.18 ft3) and WDP-8 (0.97 ft^3); these pumps are located on the 95 feet elevation floor below the flood level.
  - Letdown coolers MUHE-1A/1B/1C (variable); displaced volume is calculated based on flood level. Only volume below flood level is credited.
  - Letdown cooler concrete pad (11.25 ft^3); pad is below flood level.
  - RC drain tank (WDT-5) concrete pad (35 ft^3); pad is below the flood level.
  - Reactor Coolant Pump (RCP) lube oil tanks LOT-4A/4B (variable); displaced volume is calculated based on flood level. Only volume below flood level is credited.
  - RB floor wedge (variable); displaced volume is calculated based on flood level. Only volume below flood level is credited.

  Additional equipment exists on the lower CR3 containment elevation, between the minimum and maximum calculated flood levels. The above list only includes equipment located below the minimum flood level.

- Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source.

  The potential sources of water, and volume from each (Reference 15):
  - RCS; the break is assumed to be located at the highest point of the hot leg "candy cane." Therefore, the RCS is assumed to remain full (0 ft^3 contribution).
  - Core Flood Tanks (CFT-1A/1B); for small break LOCAs, the RCS pressure is assumed to remain above the core flood actuation pressure (0 ft^3 contribution). For large break LOCAs, the minimum ITS-allowable volume is used (1940 ft^3 contribution).
  - Borated Water Storage Tank (BWST); the BWST is assumed to be at the minimum ITS-allowable volume prior to the event. Transition to recirculation begins when the BWST reaches 15 feet (16 ft indicated). Only the volume above the 16 ft indicated level is considered in the sump level calculation (35,396 ft^3 contribution).
  - Makeup Tank (MUT-1); the makeup tank is cross-connected to the BWST and will provide a suction source during the initial drawdown of the BWST. This tank is assumed to be at the low level alarm point prior to the event, and is completely drained (284 ft^3 contribution).
  - Each of the contributing volumes is converted to an equivalent volume at the analyzed sump temperature of 204.7°F.

- 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.

  The NPSH available calculations were performed using assumptions consistent with guidance in NEI 04-07 and its associated SER. No containment overpressure was credited, except that the containment pressure was assumed to equal the saturation pressure corresponding to the sump water temperature. It is also assumed that the containment dry air pressure remains constant; i.e., no credit was taken for elevated containment pressure resulting from post-LOCA heating of the air. This approach is consistent with the guidance of NEI 04-07.

- Containment Accident Pressure/Sump Water Temperature Assumptions

  NPSH available calculations were performed for saturated sump water at a temperature of 204.7°F. The basis for selecting this temperature is provided in the following two paragraphs.

  The minimum post-accident containment pressure was set equal to the minimum containment pressure allowed by ITS (12.7 psia) for plant operation. The saturation temperature corresponding to this minimum containment pressure (204.7°F) was then established as the limiting sump pool temperature for purposes of determining NPSH available. For sump pool temperatures above the limiting temperature, containment pressure is set equal to the saturation pressure (i.e., vapor pressure) corresponding to the sump pool temperature. For sump pool temperatures at or below the limiting temperature, containment pressure is set equal to the minimum post-accident containment pressure (12.7 psia).

As sump pool temperature increases above the limiting temperature, water viscosity decreases. This results in decreased head loss due to piping friction losses and flow through the debris bed (in both cases assuming constant volumetric flow). Since, for this case, containment pressure is set equal to the saturation pressure corresponding to sump pool temperature, the effect of increased sump pool temperature is an increase in NPSH available (due to decrease in head loss across the strainer and in the suction piping).

As sump pool temperature decreases below the limiting temperature, the corresponding saturation pressure (i.e., vapor pressure) decreases below the minimum post-accident containment pressure, resulting in a subcooled sump pool; this effect increases the NPSH available. However, as sump pool temperature decreases below the limiting value, water viscosity increases. This results in increased head loss due to piping friction losses and flow through the debris bed (in both cases assuming constant volumetric flow); this effect decreases NPSH available. A parametric evaluation was performed to determine the impact of decreasing sump pool temperature on head loss. This evaluation demonstrated that the relatively small increase in head loss was overwhelmingly compensated by the sump pool sub-cooling effect (i.e., sump pool saturation pressure decreasing below the minimum post-accident containment pressure). For example, as the sump pool temperature decreases from 204.7°F to 125°F, the head losses increase by less than 0.5 feet. Over this same temperature range, the $NPSH_a$ increases by approximately 23 feet due to sub-cooling of the sump water. Therefore, the net effect of decreased sump pool temperature, that being below the saturation temperature, is a significant increase in NPSH available, thus increasing NPSH margin. The following conclusion was reached:

The maximum RB sump temperature is 243°F following transfer to sump recirculation, but the preceding discussion demonstrates that the limiting NPSH available occurs when the sump pool temperature reaches 204.7°F.

- Containment Accident Pressure/Vapor Pressure/Sump Liquid Temperature

  As stated above, containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.

- NPSH Margin Results

  (Head loss term results are based on a preliminary test report.)
  NPSH calculations were performed to establish the ECCS and CS pump NPSH margins. The NPSH margin, less the debris and chemical precipitate induced head loss across the strainers, is shown in the following table:

Clean Strainer NPSH Margin (204.7°F Water Temperature)

	DHP-1A	DHP-1B	BSP-1A	BSP-1B
Flow Rate (gpm)	2992	2992	1362	1362
NPSH Margin (ft)	2.9	2.2	3.0	2.5

This table is based on a LBLOCA low-low water level of 2.12 feet above the sump (calculation M90-0023, Reference 15) with the DH pumps in piggy-back supplying 580 gpm to an HPI pump, 2312 to the vessel, and 100 gpm in mini-recirculation.

The HPI pumps have over 200 feet of NPSH margin when piggy-backed to the LPI pumps (Reference 14, Sections 3.6.2 and 3.8).

In summary, when factoring conservatively low recirculation water levels, conservatively high pump flows, a maximum debris laden strainer, and only static water level as the driving head, the NPSH margin remaining is that shown in table below. This demonstrates adequate NPSH margin for any post-LOCA condition that could develop at CR3.

Debris-Laden Strainer NPSH Margin (204.7°F Water Temperature)

	DHP-1A	DHP-1B	BSP-1A	BSP-1B
Flow Rate (gpm)	2992	2992	1362	1362
NPSH Margin (ft)	2.8	2.1	2.9	2.4

h. 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.***

Supplements previous information:

- CR3 Coating Systems

  CR3's originally specified qualified coating systems currently represent the overwhelming majority of the applied coatings that could be subjected to LOCA jets. Those specific DBA qualified coating systems are:

  Plasite 7155NP (epoxy steel primer) or
  Plasite 9028MI (epoxy concrete surfacer), with a
  Plasite 9009 epoxy topcoat.

  Since 10CFR50 Appendix B Plasite products are no longer commercially available, the DBA maintenance coating currently specified at CR3 is:

  Carboguard 890N

  Additionally, a thin film of high-heat aluminum coating was applied to the Nuclear Steam Supply System (NSSS) equipment when originally supplied for installation. Areas having this coating application are covered with protective insulation.

- Assumptions

  The following assumptions apply to the CR3 transport analysis relative to coatings:

  - It was assumed that the settling velocity of paint particulate can be calculated using Stokes' Law. This is a reasonable assumption since the particulate debris is generally spherical and would settle slowly (within the applicability of Stokes' Law).

  - It was conservatively assumed that all debris blown upward would be subsequently washed back down by the containment spray flow with the exception of any pieces of debris held up on grating. The fraction of debris washed down to various locations was determined based on the CR3 geometry and the BS flow pattern.

  - During pool fill-up, it was assumed that a fraction of the coatings debris (from the ZOI) would be transported to inactive areas, as well as some debris directly to the sump screens as the inactive and sump cavities fill with water. These fractions were determined based on the ratio of the cavity volumes to the pool volume at the point when the cavities are filled.

- It was assumed that the unqualified coatings would be uniformly distributed in the recirculation pool. This is a reasonable assumption since the unqualified coatings are scattered around containment in small quantities.

- It was assumed that the degraded qualified coatings would be uniformly distributed inside the D-Rings since these coatings are applied on the inside of the D-Ring walls.

- It was assumed that the debris washed down from the upper containment by the spray flow would remain in the general vicinity of the location where it is washed down until recirculation begins. This is a reasonable assumption since there is no preferential pool flow direction during pool fill-up after the inactive and sump cavities have been filled. Also, this assumption is somewhat conservative since the local turbulence caused by the sprays would increase the potential for debris to transport from these locations (as opposed to debris being distributed to regions of the pool with lower levels of turbulence and velocity and therefore lower transport potential).

- With the exception of debris washed directly to the sump screens or to inactive cavities, it was assumed that the fine debris that is not blown to the upper containment would be uniformly distributed in the recirculation pool at the beginning of recirculation. This is a reasonable assumption, since the initial shallow flow at the beginning of pool fill-up would carry the fine debris to all regions of the pool.

CR3 installed a recirculation flow distributor, intended to minimize pool velocity and induce debris settling. Also, a debris interceptor was installed for the purpose of trapping sliding or tumbling debris. With these enhancements and the above assumptions, the following conclusions were reached, relative to coating transport (Reference 18):

- DBA qualified epoxy coatings located within the HELB ZOI of 4D are assumed to fail as particulate matter disbursed uniformly throughout containment, with 8% settling into quiescent pools and 92% reaching the sump.

- Similarly, all of the unqualified high-heat aluminum exposed by the break is assumed to fail, with 92% reaching the sump.

- All of the unqualified and degraded qualified paint chips in containment are assumed to reach the pool, with the overall transport fraction being equal to the recirculation transport fraction. The fraction of degraded qualified epoxy paint chips transported to the debris interceptor is determined to be 39%, but none (0%) would reach the sump due to the effectiveness of the installed device. The fraction of unqualified epoxy paint chips transported to the debris interceptor has been determined to be 32%, with only 18% of the total amount ultimately reaching the sump.

Coating Debris Transport Metrics

	Size	Terminal Settling Velocity (ft/sec)	Reference	Calculated Minimum TKE Required to Suspend (ft^2/sec^2)	Incipient Tumbling Flow Velocity (ft/sec)	Reference
Coating Debris	10-micron particulate (120 lbm/ft^3)	3.0E-04	Calculated per Stokes' law	1.3E-07	NA	-
	10-micron particulate (96 lbm/ft^3)	1.8E-04	Calculated per Stokes' law	4.6E-08	NA	-
	10-micron particulate (90 lbm/ft^3)	1.5E-04	Calculated per Stokes' law	3.2E-08	NA	-
	10-micron particulate (94 lbm/ft^3)	1.7E-04	Calculated per Stokes' law	4.1E-08	NA	-
	Epoxy paint chips	0.13	NUREG/CR-6916	2.5E-02	0.27	NUREG/CR-6916

Coating Debris Fraction Transport to the RB Sump

Debris Type	Size	Transport Fraction
Qualified Plasite 9028 MI Coatings (inside ZOI)	Particulate	92%
Qualified Plasite 9009 Coatings (inside ZOI)	Particulate	92%
Unqualified Hi-Heat Aluminum Coatings (inside ZOI)	Particulate	92%
Unqualified Coatings (outside ZOI)	Chips	18%
Degraded Plasite 9028 MI Coatings (outside ZOI)	Chips	0%
Degraded Plasite 9009 Coatings (outside ZOI)	Chips	0%

- Strainer Head Loss Testing

  CR3 performed prototypical head loss testing at the Alion Science and Technology test facility in Warrenville, Illinois (see section 3.f for test details). The amount of coatings debris used in the test was the quantity of qualified and unqualified coatings calculated to reach the sump, scaled by the area ratio (test strainer area to CR3 strainer area). All of the qualified and unqualified coatings were treated as particulate. A surrogate material was used to represent the coatings debris in the test, with an amount that gave an equivalent volume of particulate as the scaled coatings particulate. The surrogate was Sil-Co-Sil 53 (fine ground silica).

  Since the testing used a relatively small amount of fiber, paint chips were also introduced in the test to represent an equivalent scaled volume of unqualified coatings reaching the sump. The surrogate for the chips was paint chips from Chips Unlimited. Note that this conservatively resulted in twice the volume of unqualified coatings in the test.

- Basis for Surrogates

  The head loss testing used Sil-Co-Sil 53 ground silica manufactured by U.S. Silica Company as a surrogate material for the particulate coatings debris. The ground silica is a spherical particulate ranging in size from just under 1 μm to approximately 100 μm. The specific gravity of this material is 2.65, corresponding to a density of 165 lb/ft^3. The qualified and unqualified coating densities at CR3 range from 90 lb/ft^3 to 120 lb/ft^3. An adjustment was made to compensate for the difference in the density of the material such that an equivalent volume of the surrogate material was used. The majority of the plant coatings are on the order of 10 μm or greater. Because a significant portion (approximately 40%) of the ground silica material is less than 10 μm, the ground silica would tend to produce a debris bed with a lower porosity and higher surface-to-volume ratio than a debris bed comprised of coating material. Thus, the use of ground silica as a surrogate for coating material is conservative.

  Paint chips from Chips Unlimited were used as a surrogate for the unqualified coatings debris. The chips had a thickness of 4-6 mils, compared to a CR3 applied thickness of 6 mils, and were sifted through sieves to obtain sizes ranging from 1/8 inch to 3/4 inch. The density of unqualified coatings at CR3 is 94 lb/ft^3, and the density of the surrogate paint chips was 105.9 lb/ft^3. An adjustment was made to compensate for the difference in the density of the material such that an equivalent volume of the surrogate material was used. The paint chip surrogate closely replicates the CR3 unqualified coatings characteristics, and was sized to facilitate strainer blockage even with a clean screen surface area. Therefore, the use of paint chips as a surrogate is appropriate.

- Coating Debris Generation

  The following assumptions pertain to the coatings debris generation calculation:

  - The analysis of unqualified coatings within the ZOI assumes that all the RCS high heat aluminum coating covered by failed insulation in the North D-Ring is destroyed and generates failed coatings debris.
  - It is considered that 30% of the coatings on the interior walls of the D-Ring are degraded and will fail in the post-LOCA environment. The 30% is taken from a visual walkdown of the containment.
  - Although the SER currently states that a 10.0 D ZOI should be used for qualified coating systems, for purposes of the debris generation calculation a 4.0 D ZOI is used. Testing was performed using coatings systems that have been previously determined to be DBA Qualified/Acceptable for use inside PWR containments. The objectives of the testing were to simulate the processes and phenomena associated with a postulated PWR blowdown, determine the destructive effects of the resulting jet impingement on coating systems used inside PWR containments, and gather the information necessary to define a technically defensible, realistic ZOI for DBA Qualified/Acceptable coating systems used inside PWR containments. The results of this testing program are presented in WCAP-16568-P, "Jet

Impingement Testing to Determine the ZOI for DBA-Qualified/Acceptable Coatings," Reference 52).

Within the WCAP, the applicability of this test data to the family of DBA Qualified/Acceptable epoxy coatings was evaluated and it was determined that epoxy coatings that have been demonstrated to be DBA Qualified/Acceptable will perform similarly when applied in the manner in which they were qualified, regardless of the manufacturer of the coating system. Therefore, it is concluded that the results of the testing in WCAP-16568-P are applicable to the CR3 DBA Qualified/Acceptable epoxy coatings. The testing demonstrated that no jet impingement damage occurred for epoxy topcoats on either carbon steel or concrete substrates at a minimum ZOI of 1.37 L/D. A ZOI of 4.0 L/D for DBA qualified coatings is therefore supported by the testing.

- For qualified coatings within the ZOI, the quantity of paint debris is based on the surface area of a sphere having a radius equal to the ZOI (i.e., 4.0 L/D). This overestimates the quantity of qualified coatings debris, as the surface area of the sphere exceeds the surface area of coated lines and components within the sphere.

- CR3 assumes that all qualified coatings and all unqualified coatings within the ZOI to fail as 10 μm fines. The NRC staff pilot program effort found the treatment of qualified and unqualified coatings within the coatings ZOI to be consistent with Section 3.4.3.3.3 of the GR.

- All unqualified and degraded Services Level 1 coatings, except Inorganic Zinc, outside of the Coatings ZOI are assumed to fail initially as paint chips with a thickness equivalent to the original coating thickness. The Electric Power Research Institute (EPRI) report for Original Equipment Manufacturer (OEM) coating failures (EPRI Report 1011753, "Design Basis Accident Testing of Pressurized Water Reactor Unqualified Original Equipment Manufacturer Coatings") documented autoclave DBA tests of non-irradiated and irradiated unqualified OEM coatings. The EPRI report documented testing on various types of unqualified coatings, alkyds, epoxies and Inorganic Zinc (IOZ). A 100% failure of unqualified coatings is conservative as the EPRI report has indicated that only about 20% of unqualified OEM coatings actually detached as a result of autoclave DBA testing. Detachment is considered failure of a coating system. Any non-detached coatings are not considered failed. Thus, this illustrates that assuming 100% failure is significantly conservative. The coatings are assumed to detach initially as chips that have a thickness equivalent to the original coating thickness which is consistent with the EPRI document, but due to tumbling in the containment pool and potential further degradation during transport, the unqualified and degraded Service Level 1 coatings are assumed to have a failed size of 25 μm paint chips at the surface of the strainers. Use of this chip size (i.e., 25 μm) is consistent with findings documented in the EPRI document. The report concluded from the autoclave tests that the failed coating average particle size was 83 μm for samples 1-19, and 301 μm for samples 20-42. These particles were retrieved from the DBA test autoclave from recirculating loop filters, and hence the coating debris was constantly being recirculated throughout the autoclave test. Hence the EPRI tests conducted on OEM coatings indicated that the average failed particle size could be larger than that which is assumed for this calculation. Also, the Boiling Water Reactor Owners Group (BWROG) report, "Failed Coating Debris Characterization," uses autoclave test data gathered by the BWROG Containment Coating Committee to simulate LOCA exposure and gain insight into post-LOCA failure mechanisms. The results showed that all but the inorganic zinc paint failed in macro-sized pieces. Inorganic Zinc coatings are assumed to fail as 10-μm fines, in agreement with the SER and the data from the report.

- Debris Characteristics

The following table summarizes the entire coating debris source term and the assumed properties of each:

Failed Coating Debris Source Term

Coating Description	Failed Surface Area (ft^2)	Applied Thickness	Volume (ft^3)	Density (lb/ft^3)	Weight (lbs)	Failed Size
Plasite 9028 MI	1809.6	8 mil	1.21	119.8	144.5	10 μ
Plasite 9009	1809.6	8 mil	1.21	95.5	115.6	10 μ
Hi-Heat Aluminum	479	0.75 mil	0.03	90	2.7	10 μ
Unqualified Coatings	1000	6 mil	0.5	94	47.0	25 μ
Failed D-Ring 9028MI	9066	8 mil	6.04	119.8	723.6	25 μ
Failed D-Ring 9009	9066	8 mil	6.04	95.5	576.8	25 μ

- The CR3 licensing basis requires that protective coatings for Service Level I (SL I) be DBA qualified, and meet the procurement, application, and inspection quality requirements of ANSI N101.4-1972. The coatings that have been used in SL I at CR3 have been qualified for the plant specific DBA conditions in accordance with ASTM D3911-80. CR3 conducts periodic condition assessments of SL I coatings to identify areas with degraded coatings. The condition assessments utilize inspection techniques and acceptance criteria that are consistent with the ASTM D3911 DBA qualification tests.

  Degraded SL I coatings that are identified during condition assessments are conservatively quantified and considered as potential debris. The potential debris quantity is evaluated against previously established limits based on the impact of coating debris on the sump strainer performance. The quantity of degraded qualified coatings may be determined in conjunction with removal of the degraded coatings, when the extent of the degraded area is not limited by a physical boundary. The soundness of adjacent qualified coatings is ensured by removal of coatings not meeting adhesion criteria consistent with Steel Structures Painting Council, SSPC-SP 2, "Hand Tool Cleaning."

  Areas with degraded coatings are prioritized, removed, and repaired as appropriate. Maintenance or repair coatings are applied using approved procedures that meet the licensing basis requirements, thereby ensuring that the DBA performance requirements are maintained.

i.Debris Source Term

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

  GL 2004-02 Requested Information Item 2(f)
  A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced into containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CS 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.***

Revises previous information

- Housekeeping and FME Programmatic Controls
  - Aggressive containment cleaning and increased foreign material controls have been established. Surveillance Procedure, SP-324, "Containment Inspection," (Reference 40) has been revised to require more detailed RB inspections following an outage. This includes separate areas of the RB being inspected by teams typically led by Senior Reactor Operators. This procedure also performs verification of drainage path availability for all RB floor drains and the two (2) Fuel Transfer Canal (FTC) drains. This procedure provides instructions to inspect the RB after a maintenance outage, quarterly inspections or limited maintenance jobs which require entry into containment. It serves to ensure post-LOCA recirculating water flow paths

are open and unobstructed. This procedure also contains instructions to ensure no latent debris is present which can be carried to the containment sump. Latent debris is defined in the procedure as:

> *Latent debris is defined as dirt, dust, paint chips, fibers, pieces of paper, plastic, tape, adhesive labels, fines or shards of thermal insulation, fireproof barrier, rags, clothing, or other materials that are present in the containment prior to a postulated break in a high-energy line inside containment and could be transported to the RB sump and cause restriction of the LPI pump suction during LOCA conditions.*

The acceptance criteria for latent debris in the procedure are:

> *No latent debris is observed during the required visual inspections of Containment areas.*
> *While "white glove" cleanliness is NOT required, reasonable effort should be made to minimize latent debris to the extent possible.*

- o A checklist item to discuss housekeeping requirements for work inside the RB has been added to Administrative Instruction, AI-607, "Pre-job and Post-job Briefings."

- o The equipment labeling procedure (Reference 44) specifies the use of labels that will not readily transport and potentially impact sump recirculation. For example, equipment labels used inside the containment are required to be stainless steel with a porcelain enamel coating, which is not expected to contribute to debris source term or transport under maximum sump pool velocities. The attaching device for stainless steel tags is specified to be stainless steel braided wire. Normally, only qualified materials are allowed inside containment. However, many original (plant construction era up to 1997) adhesive vinyl equipment labels are present in containment. The sump strainer head loss analysis (Reference 20) accounts for these labels with adequate margin for uncertainty in the actual count, and it accounts for limited use of paper and plastic equipment clearance tags. The equipment tag replacement program (with porcelain-coated stainless steel) is an ongoing process, which continually recovers design margin as the labels are upgraded.

- Permanent Plant Change Programmatic Controls

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 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 resolution of GSI-191 are:

- Corporate procedure EGR-NGGC-0005, "Engineering Change," (modification procedure) was revised to provide screening criteria regarding the creation or alteration of potential sources of debris that could interfere with ECCS suction from the recirculation sump or with operation of the associated pumps; addition or reduction in materials in containment that could affect post-accident chemical precipitate formation; and the creation or modification of openings in the crane wall, bio-shield wall, secondary shield wall or D-Ring wall (including any associated screens or similar barriers installed over the openings), or modify containment floors, which could alter water flow to the ECCS recirculation sump.
- Specification CR3-M-0006, "Reflective Metal Insulation for Steam Generators and Reactor Building Piping," was issued to ensure future changes or additions to insulation in containment do not increase fiber source term.
- The inputs and assumptions for debris generation, debris transport, head-loss determination (including chemical effects considerations), upstream effects (included in water level calculation), and downstream effects analyses and associated testing have been documented in approved engineering documents to facilitate evaluation of conditions that may be contrary to

analysis and modification input assumptions and to ensure that future changes to the plant may be readily evaluated against these design and licensing basis criteria.

- Maintenance Activities

Maintenance activities are controlled by plant procedures to ensure sump performance is not compromised. The containment inspection procedure (SP-324) discussed above is implemented after all maintenance activities to ensure all tools, equipment, latent debris, etc. are removed. The pre-job and post-job brief procedure (AI-607), which is used for maintenance activities inside containment, includes housekeeping with an emphasis on reactor building cleanliness.

Temporary modifications are addressed by the same corporate procedure as permanent modifications, and therefore are subject to the same design considerations and impact reviews. See "Permanent Plant Change Programmatic Controls" above.

- Recent or Planned Insulation Change-out

The following insulation change-outs have been completed:

- The NUKON insulation on the upper pressurizer head was replaced with RMI during RFO-15 (Fall 2007). This reduced the NUKON source term from 50 ft^3 to 10 ft^3.
- Approximately 12 ft^3 of mineral wool insulation was removed from the steam generator blowdown lines in each of the D-Rings.

CR3 will be replacing both steam generators in RFO-16 (Fall 2009). As part of that project, all of the insulation on the old generators will be removed and new RMI will be installed on the new generators. In addition, all remaining mineral wool insulation on the blowdown lines and drain lines will be removed and replaced with RMI, and the remaining NUKON insulation within the D-Rings will also be removed and replaced with RMI. This will result in a fiber source term of 0 ft^3 (excluding latent fiber) for all LBLOCAs. Although it is expected that the fiber source term will be 0 ft^3, a quantity of 10 ft^3 of fiber was assumed in the analyses and testing for conservatism and to bound the small amount of fiber that will remain for the SBLOCA cases.

- Modification of Existing Insulation

CR3 has not modified existing insulation, other than removal as described above, to reduce the debris burden at the sump strainers.

- Modifications to Equipment/Systems to Reduce Debris Burden

CR3 has not modified any systems or equipment to reduce the debris burden at the sump strainers.

- Containment Coatings Program Improvements

CR3 has not made any changes to the containment coatings program.

j. 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.***

Supplements previous information:

As stated previously in this document, the overall strategy for CR3 includes more than just increasing the Reactor Building (RB) sump strainer surface area. CR3's resolution to GSI-191 and GL 2004-02 involves a variety of design features integrated into a comprehensive set of changes. The design changes take advantage of the physical geometry of the CR3 containment layout with the basic intent being to force suspended and tumbling debris through a tortuous flow path to induce settlement and entrapment, while optimizing the post-LOCA recirculation water flow characteristics to minimize debris transport to the sump. Additionally, the water inventory available to meet sump demand is assured by providing higher confidence that recirculation flow paths remain clear and unobstructed.

- The following major features of the sump screen modification were completed during RFO-14 (Fall 2005):

  1) Sump strainer: The original ¼ inch square mesh sump screen (86 ft^2 of flat plane screened area) was replaced with a complex geometry sump strainer (Enercon top hats) that has an effective surface area of 1139 ft^2 (Reference 11). The new strainer is manufactured from perforated stainless steel plate, rolled and welded into pipe shapes (Refer to Enclosure 5 and Enclosure 6). The plate thickness is 14 gauge and the perforations are 1/8 inch in diameter. This perforation size was selected to preclude blockage of downstream piping components, of which the minimum identified opening (throttle valve, orifice, spray nozzle, etc.) is 3/16 inch. The new strainer assembly consists of a 4 x 8 array of vertical perforated pipes that will be installed in the existing sump. Thirty (30) of the strainer sections are made from two concentric perforated pipes. The diameter of the outer pipe is 12 inch and the diameter of the inner pipe is 8 inch. The annular gap between the inner and outer pipe is sealed at the top. Two (2) of the strainer sections are made of a single perforated 12 inch diameter pipe, with a removable top to permit access for inspection and/or cleaning below the assembly. Each top hat strainer assembly is fastened to a stainless steel support structure located near the bottom of the sump pit. Fluid from the sump pool flows from the inner pipe ID and the outer pipe OD into the annular gap between the two pipes. The filtered fluid then flows through the annular gap, into the sump below the strainer support structure, and finally into the sump outlet piping. The sump outlet piping has been modified by improving the existing square-edged flange entrance with a bell mouth shaped flange entrance in order to reduce the head loss value (equivalent to approximately 6 inch of water column improvement at full design flow). The larger strainer accommodates the maximum postulated quantity of accident generated and latent debris that could reach the sump, without structurally overloading the strainer or changing the effective strainer complex shape to the circumscribed area (which could reduce to 2 flat planes if overload occurs). The larger strainer ensures that ECCS/CS NPSH margin is assured, even when considering the amount of post-LOCA debris that has been recently determined by mechanistic analyses to have the potential to reach and accumulate at the sump.

  2) Strainer trash rack: The containment sump trash rack was increased in size from approximately 55 ft^2 of horizontal surface area to approximately 100 ft^2 of horizontal and 15 ft^2 (25 lineal feet) of vertical surface areas (Reference 11). The horizontal trash rack surface is stainless steel floor grating, constructed of 1-1/2 inch x 3/16 inch bearing bars and 5/16 inch cross bars, with about 77% open area in 4 inch x 1 inch segments. The vertical trash surface is fabricated from 3/8 inch x 2 inch stainless steel bar, vertically spaced in approximately 8 inch x 7-1/4 inch open segments. The larger trash rack surface area is more tolerable of large debris

capture, while the vertical sections preclude the possibility of a large piece of debris (insulation panel, plastic sheet, etc.) from excessively obstructing the flow to the strainer below and starving ECCS and CS pump demand.

3) Curbing and compartmentalization: The sump is protected by a 4 inch high curb, located within the periphery of the trash rack. Additionally, the recirculating coolant must negotiate 7 inch high curbs at the D-Ring personnel access door and 12 inch high curbs at each 1 foot x 1 foot flow scupper out of the bio-shield wall. All of these curbs are pre-existing and are not credited for debris capture, but they enhance the ability to capture or trap denser debris, minimizing transport to the sump. The compartmentalization and layout of CR3's RB basement floor induces a convoluted/tortuous path for debris-laden recirculating coolant flow. In addition to trapping sinking debris inside the D-Rings, in the RC Drain Tank room, in the Incore Trench, and in the hallway outside the north D-Ring, floating debris will tend to be retained inside the D-Rings and RC Drain tank room due to the 2 foot minimum water level depth being higher in elevation than any of the unconfined exit paths (the D-Ring personnel exit has a cyclone fence gate).

4) Flow distributor: To further optimize the post-LOCA containment pool flow characteristics and induce sedimentation of debris, a flow distributor constructed from stainless steel was added to minimize localized flow streaming and to reduce bulk recirculation flow turbulence (References 11 and 19). The physical design features of the distributor were established by a series of Computational Fluid Dynamics (CFD) analysis iterations with the intention of spreading the volumetric flow rate across as large a flow area as possible, which reduces velocity following transfer from the BWST injection to RB Sump recirculation mode of cooling (conservatively assuming the minimum expected water level on the containment floor). The flow distributor acts as a baffle, providing a regulated flow through a 7.5 inch x 8 feet long opening that is about 1 foot above the floor, forcing the remaining flow around the distributor. The net effect is that the bulk fluid stream is slowed to create a nearly homogenous, low-velocity and somewhat quiescent flow pattern, minimizing turbulence that could promote debris suspension.

5) Debris Interceptor: A 15 inch high stainless steel debris interceptor was installed across the entire width of the RB floor between the D-Ring wall and the containment liner, to enhance the ability to trap sliding/tumbling floor debris that has settled (References 11 and 19). The interceptor location was selected by CFD analysis, specifically where flow velocity and turbulence is minimal, precluding debris carry-over. The interceptor is a string of seven removable structural frames in series, each about 6 feet long and covered with perforated plate having 3/16 inch diameter holes intended to permit water through-flow and to capture debris such as paint chips and fibrous matter. The 15 inch height ensures adequate weir height is available for water over-flow with a 2 feet high (minimum) pool level, should the interceptor become completely clogged with debris. Although not expected to be challenged because of the upstream recirculation pool flow characteristics, the interceptor is capable of trapping at least 95 cubic feet of debris. This is considered to be especially important during possible sweeping/sheeting action of the water as the containment fills up with water (prior to switchover to sump recirculation).

6) Scupper covers: There are eight 1 feet x 1 feet scuppers that permit flow through the D-Ring and Reactor Coolant (RC) Drain Tank room walls, then around the D-Ring walls to the sump. Four are located on the south D-Ring (which is physically near the sump) and were covered with ¼ inch screen. This screen was replaced with 3/16 inch perforated plate (Reference 11). The four scuppers on the north D-Ring side (one in the RC Drain Tank room) are left open (not covered with perforated plate). This ensures adequate water flow paths are available and unobstructed, but forces large debris items (greater than 3/16 inch in size) through a lengthy and tortuous path before reaching the sump, thereby increasing the likelihood of entrapment or settling prior to reaching the sump.

7) Refueling Cavity Drain Trash Rack: A 19 inch x 11 inch x 17 inch box-shaped trash rack with a 5-sided through-flow strainer surface area of about 8.5 ft^2 is installed over the 6 inch diameter drain path to the Reactor vessel cavity (Reference 11). This drain path is credited in the Reactor Building Flooding analysis (Reference 15) that concludes that a minimum water level of

at least 2 feet above the basement floor is maintained. The trash rack is constructed of stainless steel floor grating (¾ inch x 3/16 inch bearing bars on 2-3/8 inch centers and ¼ inch cross bars on 4 inch centers) and sits about 6 inch above the cavity floor. This feature could create a pool depth of 6 inch of water and debris in the FTC, but provides assurance that the 6 inch diameter piping drain path remains open and that the deep end of the FTC does not hold up excessive amounts of CS water. The trash rack is structurally rugged in design, but is also protected by the D-Ring walls and the north-most fuel up-ender support structure. This results in damage during a LOCA event being unlikely.

8) RB Sump Level Instrumentation Enhancements: The original Regulatory Guide 1.97 Sump Level indicator, a ball float style device, remains as a back-up to a new Rosemount dP cell that was installed as an enhancement (Reference 12). The dP cell provides post-accident sump level indication for the plant operator at the Main Control Board and also provides the capability for Accident Assessment teams to trend the effects of debris accumulation on the sump strainer by monitoring the differential pressure across the strainer via the plant computer. This feature provides the EOF/TSC Accident Assessment Teams a means to determine if sump strainer debris accumulation is occurring and if reactionary measures, such as flow throttling or strainer backwashing, may be appropriate to ensure pump NPSH margin is maintained.

- Additional modifications necessitated by the sump strainer modification

  1) The Decay Heat thermal relief valve (DHV-44) tail pipe was shortened and a new piping support was utilized.

  2) The HPI recirculation line was modified by shortening the line and installing an elbow to redirect the discharge flow. The elbow serves to redirect the discharge flow to prevent direct impingement of the flow on the top-hat strainer assemblies. The HPI recirculation line is safety-related piping that is used during certain post-accident scenarios to ensure that the HPI pumps do not overheat as a result of too little flow.

  3) The non-safety 1 inch drain line from the collection sink on the south bulkhead wall was re-routed.

  4) Two abandoned Letdown Heat Exchanger isolation valve packing leak-off lines were shortened to eliminate interferences.

  5) The Post-Accident Sampling System supply and discharge tubing from the sump were relocated to the north of their existing locations to eliminate interferences with the strainer and associated trash rack.

k. 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 <u>Requested Information</u> Item 2(d)(vii).

> ***<u>GL 2004-02 Requested Information Item 2(d)(vii)</u>***
> ***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, jet impingement, and missile impacts 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.***

Revises previous information
The new CR3 sump strainer assembly is located within the confines of the original sump pit, remote from the RCS and completely outside the bio-shield walls. Refer to the Enclosure 5 and Enclosure 6 for layout and arrangement details and pictures.

The original sump strainer (screen) was designed in accordance with AISC 8th Edition. Consistent with this, the new strainer (designed and installed by Engineering Change (EC) 58982) conforms to AISC 8th Edition. The following load combination was used in the design of the strainer components:

Normal = DL + TL

Occasional (OBE) = DL + TL (normal) + OBE + OL

Occasional (SSE/LOCA) = DL + TL (accident) + SSE + DP + OL

Where:

DL is the load due to dead weight

OBE is the load due to an Operating Basis Earthquake (Design Basis Earthquake)

SSE is the load due to a Safe Shutdown Earthquake (Maximum Hypothetical Earthquake)

TL is the load due to thermal expansion

DP is the differential pressure loading across the strainer

OL is the load due to other occasional loads (such as strainer backflow)

The new strainer and structures associated with strainer assembly were designed in accordance with AISC Manual of Steel Construction, 8th edition. The individual top-hat assembly sections of the strainer are constructed of perforated stainless steel and were qualified by hand calculations using conventional engineering approaches. The perforated cylinders are considered as solid cylinders and the physical properties are adjusted to account for the effects of the perforations. This was accomplished by applying reduction factors for allowable stresses and modulus of elasticity.

The sump strainer supporting structure is a space frame that was qualified utilizing the GTSTRUDL computer program. Combinations of dead weight, seismic and differential pressure loads were considered. The sump strainer supporting structure is conservatively qualified for faulted loads.

The sump strainer supporting structure is subjected to various temperatures during normal operating and accident conditions. In order to accommodate the thermal expansion of the structure, bolted connections with slotted holes are designed for the long W4 & tube steel members. This allows thermal growth of the supporting structure without imposing significant additional stresses in the structural members. In order to reduce the conservatism in GTSTRUDL analysis, dynamic analysis of the strainer structure was performed.

Results of the sump strainer structural analysis (Reference 31) are as follows:

Top Hat Strainers
Bending Stress: 631 psi calculated vs. 5391 psi allowable
Axial Stress: 75 psi calculated (no allowable calculated due to minimal calculated stress)
Buckling Pressure: 3 psi design vs. 11.7 psi allowable
Bottom Flange Weld: 66 lbs/in calculated vs. 563 lbs/in allowable

Top Hat Studs
Tension: 380 lbs vs. 2042 lbs allowable
Shear: 36 lbs vs. 1052 lbs allowable

Strainer Structural Frame
Normal Member Stress, maximum stress interaction ratio: 0.394 (<1.0 allowable)
Shear Member Stress, maximum stress interaction ratio: 0.588 (<1.0 allowable)

Local Stress in C6x10.5 Member
Bending Stress: 11087 psi calculated vs. 16875 psi allowable
Web Crippling: 915 psi calculated vs. 16875 psi allowable

Local Stress in C10x15.3 Member
Bending Stress: 5097 psi calculated vs. 16875 psi allowable
Web Crippling: 1070 psi calculated vs. 16875 psi allowable

Structural Frame Welds
Maximum interaction ratio: 0.798 (<1.0 allowable)

5/8 inch bolts
Tension: 3500 lbs calculated vs. 9498 lbs allowable
Shear: 400 lbs calculated vs. 4893 lbs allowable

3/4 inch bolts
Tension: 100 lbs calculated vs. 13675 lbs allowable
Shear: 4500 lbs calculated vs. 7046 lbs allowable

1/2 inch threaded rods
Tension: 720 lbs calculated vs. 3638 lbs allowable
Shear: 290 lbs calculated vs. 1874 lbs allowable

3/8 inch bolts
Shear: 200 lbs calculated vs. 1052 lbs allowable

1/2 inch Drillco Maxi-Bolts
Maximum interaction ratio: 0.84 (<1.0 allowable)

Previously provided information that continues to apply (re-stated here):

The only RCS related high energy line in the vicinity of the containment sump is the letdown line. All other RCS pressurized components are inside the secondary shield wall (bio-shield wall), which provides adequate protection for the sump components from expanding jets and/or missiles resulting from a line rupture. The letdown line connects to the RCS at the RCP-1D suction line (cold leg) and connects to the Letdown coolers (MUHE-1A/B/C) in their respective compartments. The letdown line, which has 2.5 inch and 3 inch NPS branches, runs 8 and 13 feet above the RB sump structure respectively, which is at least 30 pipe diameters away to dissipate any energy from a arbitrary or intermediate line break. Ruptures of the letdown line were originally postulated to occur at any location along the high energy portion of the line. However, as part of the effort to re-evaluate RCS attached piping for the effects of HELBs, all intermediate line breaks have been eliminated using the stress criteria specified in GL 87-11 (Reference 35), as approved by CR3 License Amendment Nos. 181 and 225 (Reference 34).

As a result, only circumferential terminal end breaks are postulated at the nozzle connection to the 28 inch RCS cold leg and at the nozzle connections to each of the three letdown coolers. The sump strainer and trash rack structures are protected from the effects of these break locations (expanding jets and missiles) by intervening concrete barriers (Reference 36). In addition, SER section 7.1 states that certain breaks that have been reviewed and approved by the NRC for exclusion from the plant design basis need not be considered in the sump screen structural design. Since there are no intermediate breaks that need to be postulated, the RB sump strainer is not evaluated for breaks in the high energy letdown line.

Therefore, the sump trash rack and strainer are not subject to missile loading per CR3's licensing basis, although protection is provided by the distance away from the energy source. In any event, the trash rack is designed for dead weight, seismic inertia, and 100 lbs/ft^2 of live loading (traffic or debris). The strainer assembly is designed for 3 psid in both directions (normal and backwash) in combination with dead load and seismic loads, therefore normal and upset operating loads, including the effects of debris accumulation, have been acceptably evaluated (References 31 and 32).

The other hardware changes, such as the flow distributor, debris interceptor, and FTC trash rack, are structurally qualified for hydraulic, dead weight, and seismic loadings, as appropriate (Reference 33).

Supplements previous information:

References 31, 32, and 33 provide the structural analyses for the sump strainer, the sump trash rack, and the distributors/interceptors, respectively.

The new CR3 sump strainer is a passive strainer. Although not credited for resolution of GSI-191 and GL 2004-02, CR3 does have the ability to backflush the RB sump strainer. Backflushing is possible by gravity draining either the reactor vessel (if the DH drop line can be opened), the BWST, or the spent fuel pool to the sump. The spent fuel pumps can also be used to backwash the sump from the spent fuel pool. These methods are prescribed to the Operator and Accident Assessment Teams if indications of sump blockage exist.

The RCS drop line flow rate is about 22,500 gpm when the RCS pressure is 284 psig and two-phase flow does not occur (Reference 47). The maximum flow rate from one BWST pipe (full BWST) has been determined to be about 10,000 gpm if the containment pressure is atmospheric (Reference 48). The maximum flow rate from the spent fuel pool is approximately 3265 gpm, and is therefore bounded by the RCS and BWST flow rates. The calculated strainer pressure drop associated with back flow rates of 25,000 gpm and 10,000 gpm is 0.56 feet and 0.10 feet respectively (Reference 22). The strainer is designed for 3 psid (Reference 31), or about 6.9 feet of water column and therefore can easily handle the pressure drops associated with reverse direction flow rates of this magnitude, and higher if necessary.

I. 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 CS 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 flow paths 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.***

Supplements previous information:

CR3 Calculation M90-0023 (Reactor Building Flooding, Reference 15) provides the water inventory analyses for CR3 (several sets of break conditions and temperature considerations). This analysis identifies maximum post-LOCA water depths for the purpose of determining possible equipment submergence limitations, but also establishes the minimum water levels in accordance with the recommendations contained within NEI 04-07, including flow paths that could result in the holdup of water. These flow paths include all areas into which containment spray and RCS break flow could enter. This evaluation determined that, with the exception of the fuel transfer canal drains, bio-shield wall openings that have gates or screens, or the debris interceptor installed to prevent the transport of large pieces of debris to the recirculation sump strainer, all other water return flow paths have sufficiently large openings to prevent the holdup of significant quantities of water that could challenge the conclusions reached by the containment sump minimum water level analysis. Additionally, the water inventory introduced into containment for minimum inventory purposes is based on minimum permissible ECCS injection volumes.

The evaluation assumes all floor drains (all elevations) become clogged with debris, including the 4 inch diameter drain in the deep end of the Fuel Transfer Canal that drains directly to the sump area, precluding direct drainage to the sump. This maximizes water hold-up at the upper floor elevations and in the deep end of the transfer canal, thus minimizing the volume of water actually reaching the containment floor/sump pool.

As part of the containment water level analysis, hold-up volumes were calculated for containment spray return pathways that, due to physical features such as curbs, equipment retention (e.g. dry piping, reactor vessel cavity, RCP Lube Oil Collection system, etc.), or recessed areas (e.g., sump, fuel transfer canal deep-end, instrument tunnel, etc.) would function to reduce the quantity of water available for the containment sump pool.

The containment water level analysis is the source document used to determine that the post-LOCA minimum containment water level that could exist during the recirculation phase is adequate to prevent vortexing, air entrainment, and for ensuring sufficient NPSH is available for the ECCS and CS pumps (LBLOCA is Case C.2). NPSH margin is determined by comparing Reference 14 conclusions with the conclusions reached by the water inventory analyses.

A potential choke point was identified at the bio-shield personnel access gate, which was installed to prevent inadvertent access during plant operations. To ensure that this gate will not become a debris interceptor and hold up necessary water volume for the sump, the lower 10 inch portion of the 2 inch x 2 inch square mesh screen was removed.

As part of the physical modifications installed in the plant to resolve GSI-191, a debris interceptor was installed to limit the quantity of large debris and paint chips that could interact with the recirculation sump strainer. The design of this interceptor (15 inch high) considered the potential for holding up, or choking, the necessary water flow to the sump strainer. The design ensures that even if fully blocked by large debris, sufficient flow area would be available over the top to provide the required inventory to the recirculation sump strainer.

There is a 4 inch high curb surrounding the containment sump. The bio-shield wall has eight 12 inch x 12 inch scuppers with the low edge at 12 inch above the floor. The personnel access door has a 7 inch high curb. The new interceptor is 15 inch high. All of these obstructions are below the minimum predicted water levels which are 25.44 inch (LBLOCA), 23.04 inch (SBLOCA), and 22.08 inch (minimum submergence due to the maximum postulated sump temperature). CFD analysis (Reference 18) shows adequate weir height is available over these obstructions to meet sump flow demand with negligible impact on water level at the sump (minimal elevation gradient). Therefore, there is no adverse impact on the water holdup conclusions due to these curbs and/or compartments.

The required flow paths for returning water to the containment sump pool include the 6 inch diameter refueling cavity drain, the stairwells connecting the various elevations of containment, the perimeter annulus at each floor, the crane well, and the submerged openings (doorway and scuppers) within the bio-shield structures.

The reactor cavity drains include a 4-inch drain pipe that is protected by a fine strainer (assumed to completely clog with debris) in addition to the 6-inch drain pipe to the reactor vessel cavity which has a new debris barrier installed that is sufficiently large [19 inch x 11 inch wide x 17 inch tall] to prevent any credible debris, that may be generated as a result of the break, from blocking this flow path. The amount of water hold-up in the fuel transfer canal is calculated to be 1524 ft^3 and the reactor vessel cavity hold-up is calculated to be 5117 ft^3.

Revises previous information:

The following table represents the total water inventory assumed to be held up elsewhere inside containment and not available for sump pool recirculation height contribution (leaving a minimum of 21,436 ft^3 at the sump over the 10,704 ft^2 floor area), at worst case NPSH temperature for LBLOCA conditions (204.7°F):

Source	Volume (ft^3)
1. Elevation 160' and 119' Floor Slope (blocked floor drains)	478 + 419 = 897
2. Reactor Cavity >El. 104'	5,117
3. Fuel Transfer Canal	1,524
4. Instrumentation Tunnel < El. 104')	1,951
5. Floor Cut-out @ 94'	258
6. RB Sump Fill-up	1,124
7. BS and DH Dry Pipe Volume	520
8. RC Drain Tank	844
9. 95' Floor Drains	43
10. Core Flood Room	24
11. Condensation on Surfaces	149
12. Pressurizer Steam Space	570
13. RCS Shrinkage	2,943

14. Refueling Crane Rail Space	40
15. RCP Lube Oil Collection System	115
Subtotal:	**16,119**
16. 204.7F Sat. Steam in atmosphere	1,139
17. Containment Spray Mist in atmosphere	127
18. Break flow water in transit to the pool	32
Total:	**$V_{retained}$ = 17,417 ft^3**

NRC reviews: The upstream effects effort has been reviewed by the NRC staff as part of the Pilot Plant audit performed in 2005 (Reference 4). Relative to that review and the subsequent modifications that have been completed, the staff concluded that "the licensee has adequately reviewed the flow paths leading to the emergency sump screen for choke points, has considered the entrapment of debris upstream of the sump screen with regard to the holdup of water, and has considered the effect of holdup in planned modifications. Accordingly, the licensee's treatment of upstream effects appears to be acceptable and the NRC staff considers this a robust conclusion."

As a result of the evaluations performed and physical enhancements completed, CR3 concludes that the upstream effects analysis provides the necessary level of assurance that the required volume of water will be available at the recirculation sump in order to meet the applicable requirements as set forth in NEI 04-07 and GL 2004-02.

m. 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 CS 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 CS 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 CS 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 CS 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.***

Revises previous information:

- Summary of Methods, Exceptions, and Conclusions

  CR3 has developed calculation M04-0016, "RB Sump Screen – Downstream Effects Evaluation," to address downstream effects. This calculation was developed in accordance with Revision 1 of WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191." Evaluation of fuel inlet blockage and core cooling was performed separately and is discussed later in this section and in the next section. CR3 plans to review Conditions and Limitations in the NRC Safety Evaluation of Reference 10.

  CR3 system line-ups, mission times, flows and pressures used to bound downstream evaluations are described in these analyses. The calculation utilizes the wear and abrasion models/methodologies developed by the PWR Owner's Group (PWROG) for the industry as outlined in WCAP-16406-P to evaluate the effects of debris on the components of concern in the ECCS and BS systems due to re-circulating fluid containing the plant specific debris composition and concentration. This calculation also evaluates the susceptibility of the downstream flow paths and components to obstruction based on the guidance outlined in the WCAP, specifically, those flow paths and components of the ECCS and BS that are required to operate following a DBA. The calculations confirm that ECCS and BS operation during small-break, medium-break, and large-break LOCAs is assured to be in compliance with the CR3 accident analyses. Although it is expected that CS and HPI pumps will be shut off relatively early in most events, the analyses use a 30-day mission time for each. The following table lists the components that required wear and/or blockage evaluations:

Crystal River Unit 3 Components Requiring Evaluation per WCAP-16406-P

Component Number	Description	Evaluation Results
BS-1-FE1	Orifice	Acceptable
BS-1-FE2	Orifice	Acceptable
BS-12-FO	Orifice	Acceptable
BS-13-FO	Orifice	Acceptable
BSP-1A	Pump	Acceptable*
BSP-1B	Pump	Acceptable*
BSP-1A	Cyclone Separator	Qualified by Testing
BSP-1B	Cyclone Separator	Qualified by Testing
	BS Spray Nozzles	Acceptable
BSV-3	Globe Valve	Acceptable
BSV-4	Globe Valve	Acceptable
MUP-1A	Pump	Acceptable*
MUP-1B	Pump	Acceptable*
MUP-1C	Pump	Acceptable*
MUP-1A	Cyclone Separator	Qualified by Testing
MUP-1B	Cyclone Separator	Qualified by Testing
MUP-1C	Cyclone Separator	Qualified by Testing
MU-82-FO	Orifice	Acceptable
MU-83-FO	Orifice	Acceptable
MU-84-FO	Orifice	Acceptable
MUV-6	Globe Valve	Acceptable
MUV-23	Globe Valve	Acceptable*
MUV-24	Globe Valve	Acceptable*

Component Number	Description	Evaluation Results
MUV-25	Globe Valve	Acceptable*
MUV-26	Globe Valve	Acceptable*
MUV-590	Globe Valve	Acceptable*
MUV-591	Globe Valve	Acceptable*
MUV-592	Globe Valve	Acceptable*
MUV-593	Globe Valve	Acceptable*
DH-1-FE1	Orifice	Acceptable
DH-1-FE2	Orifice	Acceptable
DH-38-FE	Orifice	Acceptable
DH-27-FO	Orifice	Acceptable
DH-28-FO	Orifice	Acceptable
	Pressurizer Spray Nozzle	Acceptable
DHP-1A	Pump	Acceptable*
DHP-1B	Pump	Acceptable*
DHP-1A	Cyclone Separator	Qualified by Testing
DHP-1B	Cyclone Separator	Qualified by Testing
DHV-110	Globe Valve	Acceptable*
DHV-111	Globe Valve	Acceptable*
	CF Nozzle Flow Restrictor 1A	Acceptable
	CF Nozzle Flow Restrictor 1B	Acceptable
DHHE-1A	Heat Exchanger	Acceptable
DHHE-1B	Heat Exchanger	Acceptable

*Evaluations were performed using the debris depletion method

CR3 utilizes cyclone separators to provide relatively clean water to the pump seals for each of the ECCS and CS pumps. The WCAP recommends removal of cyclone separators due to potential for clogging in debris-laden fluid. The NRC's safety evaluation does not endorse this recommendation, but recommends plant-specific evaluation of cyclone separator applications.

CR3 has performed testing of cyclone separators using very conservative debris loads and fiber sizes (up to ¼ inch x 4 inch long). This includes separate tests of the Borg Warner cyclone separators installed on the HPI pumps, and the John Crane cyclone separators that have since been installed on the LPI and CS pumps (see discussion below regarding the LPI and CS pump cyclone separators). The testing concluded that the CR3 cyclone separators are not expected to become blocked with debris following a LOCA and that adequate seal cooling flow will be maintained.

The WCAP recommends that mechanical seals on pumps include disaster bushings to limit seal leakage flow if the primary seal should fail. The WCAP further recommends that the disaster bushing should be made of a harder material than carbon, such as bronze. The mechanical seals on the LPI and CS pumps include bronze disaster bushings and are in compliance with the recommendation. However, the mechanical seals on 2 of the 3 HPI pumps include carbon disaster bushings. The mechanical seals on the third HPI pump do not currently include a disaster bushing (the existing mechanical seals will be replaced with seals similar to the other HPI pumps at a future date). The WCAP discusses the limited testing of seals in debris-laden fluid, and the lack of damage to the seals during these tests. The concern identified in the WCAP is based on the postulated buildup of debris in the springs or bellows. Since CR3 employs cyclone separators to limit debris from entering the seal cavity, the failure of the primary seal due to debris accumulation is considered highly unlikely, and therefore the disaster bushing configuration for the HPI pumps is acceptable.

CR3 has conducted plant-specific bypass testing to quantify and characterize, by both optical microscopy and scanning-electron microscopy, the fibrous debris that could pass through the replacement recirculation sump screens (Reference 74). (Evaluation results are based on a preliminary report.) The characterization of the fibrous material that passed through the screens is as follows:

Percent greater than 250 microns long	85
Percent greater than 500 microns long	62
Percent greater than 750 microns long	55
Percent greater than 1,000 microns long	45
Maximum fiber length (microns)	1,690.1

These values are the most limiting values from the scanning-electron microscopy characterization. The characterization report notes that scanning-electron microscopy yields measurements that tend to be of longer fibers instead of the shorter fiber fines. Thus, use of the scanning-electron microscopy results instead of the optical results is conservative in that the scanning-electron microscopy results are biased toward longer fiber lengths, and longer fiber lengths are more likely to be trapped by components.

The size characteristics of the bypass debris further supports the employment of cyclone separators on the ECCS and CS pumps. The fibers bypassing the screen tend to be individual fibers with lengths approaching particulate sizes, and in all cases much shorter than the minimum orifice size of the cyclone separators. The microscopic density of the individual fibers (175 lbm/ft^3) significantly exceeds that of the pumped fluid, promoting efficient removal from the seal injection flow by the cyclone separators.

Fuel Inlet Blockage
AREVA performed an evaluation of the effect on core cooling from debris that may enter the reactor vessel. The evaluation used core decay heat based on a conservative power level of 3010 MWth to bound potential future power uprates. The AREVA report considered the potential to obstruct flow paths to the fuel at the following locations:

- Internals of the lower plenum, internals of the upper plenum, and core baffle region: The smallest identified opening in these areas is 1 inch, which far exceeds the size of debris that can bypass the 1/8 inch screen openings. Therefore, debris will not obstruct flow in these areas.
- Fuel inlet screen: The Fuel Assembly Lower End Fitting Debris Filters (FUELGUARD) filter at the inlet to the fuel assemblies has a nominal entrance gap of 0.100 inch, and a minimum channel restriction of 0.064 inch (0.067 inch nominal). The AREVA analysis conservatively assumed that the entire inlet filter becomes blocked (requires >0.70 ft^3 of fiber to form a 1/8 inch thick fiber bed). In this case, flow can travel through the baffle region to the core through 1-3/8 inch LOCA holes and ¼ inch wide LOCA slots in the baffle plates. Therefore, even with complete core inlet blockage, adequate flow for core heat removal exists. (A more realistic evaluation of fuel inlet blockage is discussed below).
- Lower plenum: AREVA also evaluated the potential for debris to settle and completely fill the lower plenum, blocking flow to the core. The volume of debris and chemical precipitates is insufficient to completely fill this area. Debris will not obstruct flow in this area.

See Section 3.n, "Downstream Effects - Fuel and Vessel" for additional discussion of fuel inlet blockage and peak cladding temperatures.

- Design and Operational Changes

The new sump strainer perforations are 1/8 inch diameter holes. The downstream effects evaluation determined that three components were potentially susceptible to plugging due to debris passage through the 1/8 inch diameter openings:

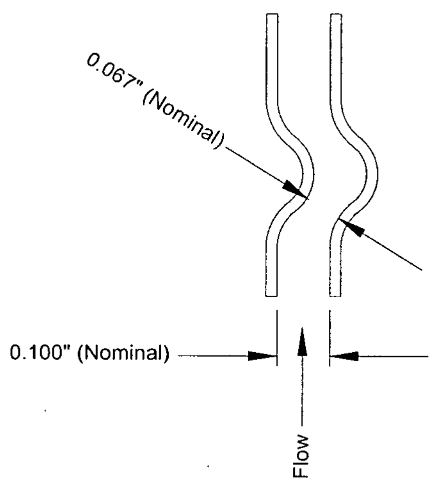
- o DH/BS cyclone separator throttle valves
- o high pressure auxiliary spray throttle valve
- o FUELGUARD

These susceptible configurations have been corrected or further analyzed:

- o The cyclone separators on the DH and BS pumps have been removed and replaced with models that do not need throttled flow. The throttle valves were removed as part of the cyclone separator replacement.

- o The HP auxiliary spray valve has been fully opened based on supporting hydraulic analyses (Reference

- o The fuel assembly inlet filters have adequate clearances, when compared to the expected debris sizes, to function without blockage. As stated above, the entrance gap is 0.100 inch (nominal). The longest fiber length identified by bypass testing was 1690.1 microns (0.0665 inch). Therefore, the fiber length is insufficient to bridge the FUELGUARD entrance gap and cause blockage. As the fibers transit the inlet filter, they encounter a smooth transition to a 0.067 inch nominal (0.064 inch minimum) gap. Although the longest fibers are theoretically capable of becoming lodged in this restriction, it is extremely unlikely, as the fibers would tend to align themselves with the flow path between the inlet filter blades. The longest fibers are also only marginally long enough to span the minimum gap if the gap is at the minimum fabricated tolerance. These factors, and the small percentage of fibers that would be expected to approach this maximum fiber length, lead to the conclusion that fuel inlet blockage will not occur.



Fuel Inlet Screen (not to scale)

n. 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)[2], 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.***

A detailed evaluation of long-term cooling was performed in accordance with WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid," revision 0. This evaluation included review and reconciliation of differences between WCAP assumptions and CR3 plant-specific design and postulated post-accident conditions. The CR3 evaluation considers the scenarios of clad temperature in a grid location (WCAP section 4.1), mid-span clad temperatures (WCAP section 4.2), the effect of time and chemistry on clad temperature with the Loss of Coolant Accident Deposition Model (LOCADM) (WCAP section 5), and blockage at the fuel assembly inlet (WCAP section 6).

For the clad temperature in a grid location, the CR3 evaluation determines that the analyzed values are very close to the CR3 values. CR3 has a lower heat flux than that used in the WCAP-16793-NP analysis, and the plant-specific grid geometry is reasonably close to that analyzed in WCAP-16793-NP. The plant-specific value of cladding thickness is slightly greater than that used in WCAP-16793-NP, and this difference is evaluated as having a very small impact on cladding temperatures. The CR3 evaluation concludes that the plant-specific cladding temperature would remain below the acceptance criteria of 800°F based on the comparison to the WCAP parameters.

Prior to issuance of WCAP-16793-NP, a separate more conservative analysis was performed by AREVA for Progress Energy specifically for CR3 (Reference 63). The result of this analysis was a peak clad temperature of 957°F at a postulated 1 inch debris plug at a spacer grid location. Key differences in the approaches between the AREVA analysis and the WCAP analysis are:

- The AREVA method assumed no radial heat transfer (only axial heat conduction in the clad).
- The AREVA method used a LHR limit of 18 kW/ft corresponding to an F_Q of 3.027, above the current COLR limit (17.3 kW/ft corresponding to 2.909 for Cycle 15). WCAP-16793-NP used an F_Q of 1.26.
- The AREVA acceptance criterion was the 10CFR50.46 acceptance criterion of 2200°F and embrittlement temperature of 1300°F versus 800°F in WCAP-16793-NP.
- The model was a hand calculation not an ANSYS computer model.

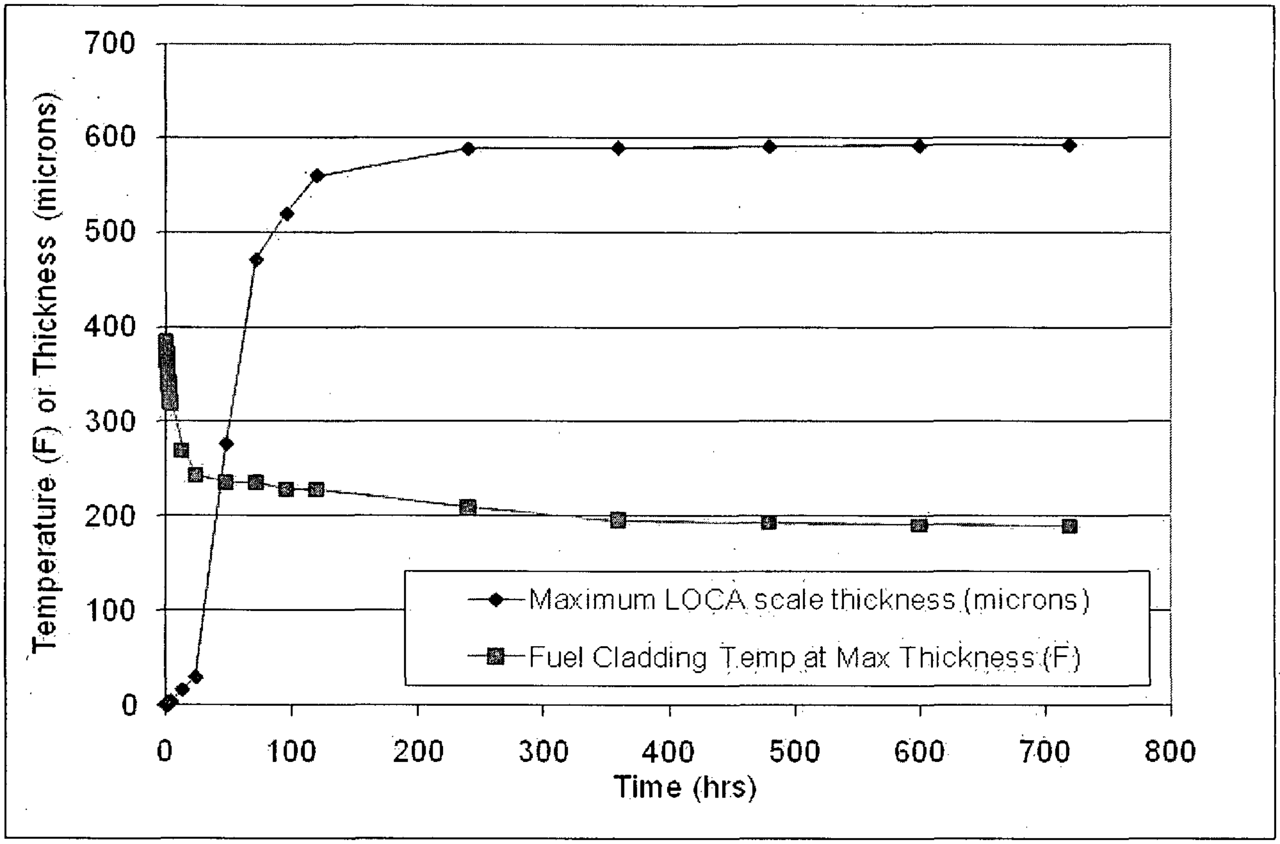
If the value were recomputed for the lower F_Q, the $qL^2/2k$ value would change from 639 to 639*1.26/2.52 = 320. The resulting peak temperature would be 638°F (302.5 + 15 +320). Where 302.5°F is the saturation temperature of the reactor coolant and 15°F is added to account for presence of nucleate boiling.

For the mid-span clad temperatures, the CR3 evaluation states that the differences between the fuel design evaluated in WCAP-16793-NP and the plant-specific fuel design are not expected to alter the applicability of Table 4-4 of WCAP-16793-NP. The CR3 evaluation concludes that the plant-specific case would result in temperatures below 800°F.

A plant-specific analysis was performed using plant data for input parameters such as sump pH and spray pH, sump temperature, containment temperature, rated reactor power, pellet stack length, and fuel rod outer diameter to determine the effect of precipitate accumulation on cladding. The analysis used the WCAP-16793-NP LOCADM model to predict the time-varying peak clad temperature as boiling in the reactor vessel increases the concentrations of materials in the vessel and increases the plate-out of scale due to heat transfer from the clad surface. Four inputs that had a large impact on clad temperature are: sump pH, containment temperature, spray mass flow, and upper plenum pressure. A higher sump pH, higher containment temperature, lower spray flow, and lower upper plenum pressure all result in higher clad temperature. The inputs for CR3 were biased such that these quantities were set conservatively. A LOCA deposit thermal conductivity of 0.2 W/m-K was used, which is consistent with WCAP-16793-NP. A peak oxide thickness of 152 microns and peak crud thickness of 140 microns was used, which is thicker than the WCAP-16793-NP default values of 100 microns and 127 microns, respectively. No plant-specific refinements were made to the WCAP-16530-NP base model. The aluminum release rate was doubled by doubling the aluminum surface area, while maintaining the total 30 day release, consistent with NRC conditions and limitations.

To account for fiber that bypasses the sump screens, LOCADM was run with increased quantities of debris in accordance with the "bump-up factor" methodology described in OG-07-534. The results of this LOCADM run show the highest cladding temperature during recirculation is less than 400°F, which is below the long term core cooling acceptance criterion of 800°F in Appendix A of WCAP-16793-NP. The cladding temperature decreases to slightly less than 200°F over 720 hours. The figure below is a plot of the LOCADM output (fuel cladding temperature and LOCA scale thickness versus time).

LOCADM Output



In order to ensure adequate flow to the core and a continuing decrease in clad temperature, CR3 has revised Emergency Plan Implementing Procedure EM-225B, "Post-Accident Boron Concentration Management" to ensure one of the active means of boron precipitation control is initiated within 48 hours of the event (the LOCADM evaluation assumed initiation at 72 hours) if the core is not sub cooled, regardless of boron precipitation indications.

<u>Fuel Inlet Blockage</u>
For blockage at the fuel assembly inlet, the plant-specific evaluation notes that the differences in the values for power distribution between the evaluation in WCAP-16793-NP and CR3 are relatively small. The plant-specific evaluation notes that the most adverse vessel design has down flow in the barrel-baffle region; however, CR3 has up flow in the barrel baffle region. Two cases were considered in WCAP-16793-NP: (1) twenty-eight peripheral fuel assembly inlets are debris-free (82% blockage) and (2) only the inlet to one

high-power assembly is debris-free (99.4% blockage). The plant-specific evaluation concludes that CR3 is bounded by the results of WCAP-16793-NP.

In addition, CR3 has LOCA slots and holes which allow extra flow into the core via the barrel-baffle. The maximum debris size that may theoretically pass through the sump screen is 0.1375 inches (1/8 inch + 10%). The slots on the bottom of the Fuelguard tie plate are 0.100 inches. However, the slots in the baffle plate are ¼ inch wide and the LOCA holes are 1 3/8 inch (Reference 1). Thus, debris cannot block flow to the LOCA holes. See additional discussion regarding fuel inlet blockage in Section 3.m. "Downstream effects - Components and Systems"

o. 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).***

General Overview and Test Results
(Evaluation results are based on a preliminary test report.)
CR3 performed prototypical head loss testing with chemical precipitates at the Alion Science and Technology test facility in Warrenville, Illinois. The tested configuration consisted of 9 single "top hat" strainers arranged in a 3 x 3 array. Each test top hat was 38 inch in length, compared to 90 inch for the actual installed top hats, due to size limitations within the test tank. The screen opening size (1/8 inch) and top hat diameter (12 inch OD and 8 inch ID) were consistent with the installed top hats. The strainer test assembly was surrounded on all sides by panels designed to simulate sump pit walls. One of the panels was clear plexiglass to allow viewing of the strainer assembly (two panels were clear during the subsequent fiber-only test).

The flow rate through the test assembly was established to obtain the CR3 strainer design approach velocity (0.0185 ft/s). The water was returned to the test tank through a horizontal sparger that discharged at the tank bottom, precluding settling of fiber, particulate, and precipitates on the tank floor. The testing was performed with tap water at approximately 90°F.

The chemical precipitates were prepared in accordance with the methodology of WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," Revision 0. The chemical precipitate loads were based on the 30-day result of version 1.1 of the spreadsheet developed for the WCAP and transmitted to the industry in letter OG-06-378. Since CR3 utilizes TSP as the buffering agent, the spreadsheet was modified to credit phosphate inhibition of aluminum corrosion in accordance with WCAP-16785-NP, Revision 0 and PWROG letter OG-07-373 (Reference 70).

A scaling factor equal to the ratio of the test strainer surface area (132.33 ft^2) to the CR3 strainer surface area (1050 ft^2)[5] was used to determine the quantity of debris and chemical precipitates for the test. The scaling factor (0.126) was applied to the quantity of debris calculated to transport to the sump, as well as to the quantity of chemical precipitates determined from WCAP-16530-NP. The test was conducted by first adding the particulates, followed by the fiber debris. Due to the potential for a clean screen area, paint chips were then added for the unqualified coatings (in addition to an equivalent amount of unqualified coatings included in the particulate load). Chemical precipitates were then added as a batch of calcium phosphate, two batches of sodium aluminum silicate and aluminum oxyhydroxide, and a final batch of aluminum oxyhydroxide. Finally, paint chips equivalent to an additional 600 ft^2 of unqualified or degraded qualified coatings (100% transport to the sump) were added for additional conservatism. Head loss was allowed to stabilize between each addition of material to the tank, as well as following the final addition of chemicals.

During the chemical effects head loss test, debris was added to the test tank directly over the "sump pit." This was intended to ensure that all debris was in the pit (not on the tank floor) and therefore had a good opportunity to attach to the top hat surface. During this test, water clarity never improved to the point where an assessment could be made regarding debris accumulation on the strainer versus settling in low turbulence zones within the sump pit (the lack of clarity is attributed to clean screen area, such that the

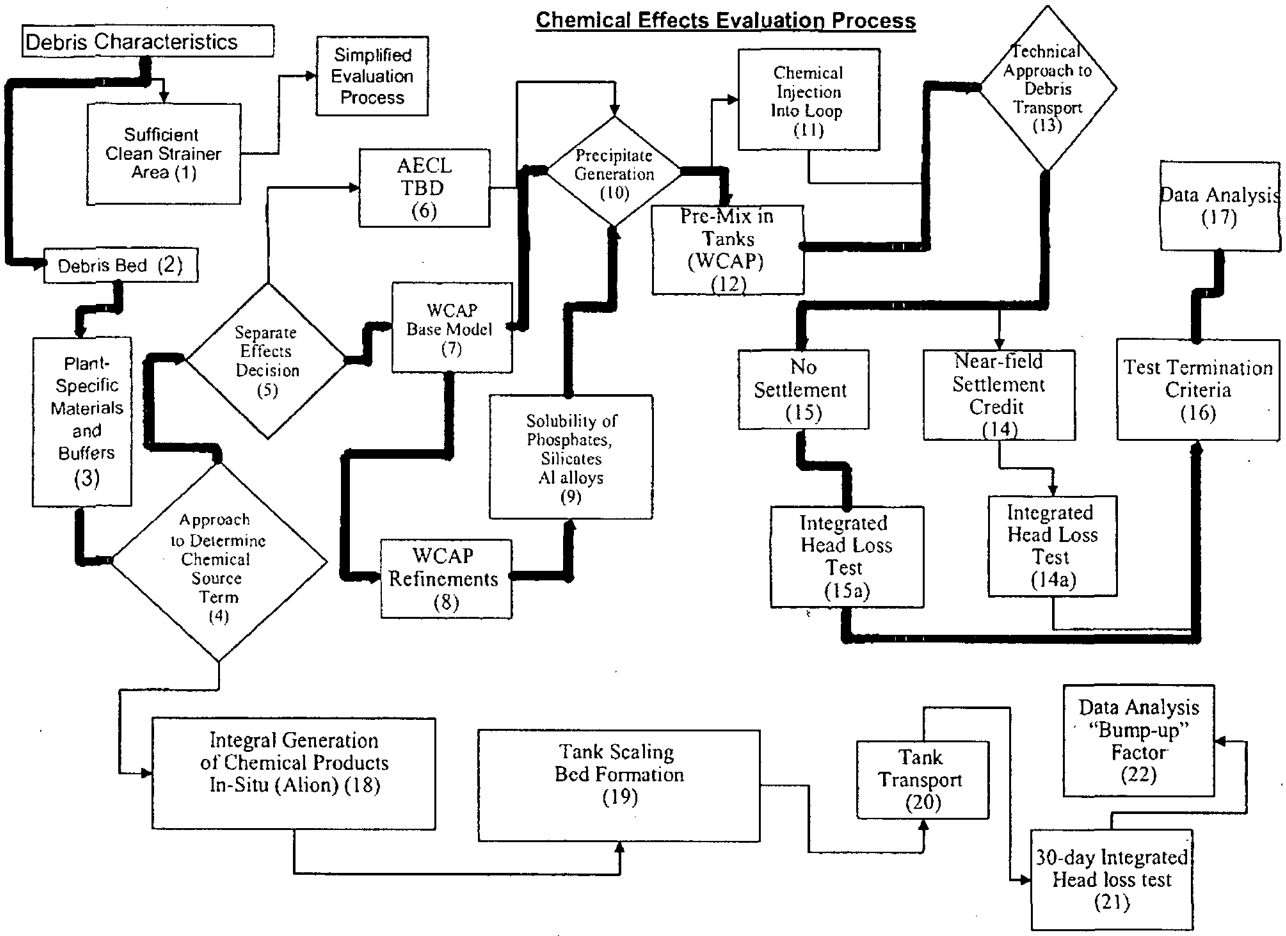
[5] A strainer surface area of 1050 ft^2 is based on 1139 ft^2 overall area minus 89 ft^2 reserved for labels, tags, etc.

debris bed could not filter out all of the particulates and precipitates). However, when the tank was drained, some amount of fiber was found on the floor of the sump pit in the immediate vicinity of the top hats. Also, as expected, a significant amount of precipitates was found on the floor of the sump pit and tank, as the precipitates remained in solution for the entire test.

A subsequent test was performed where only the fiber was added to the tank. This test was performed to: (1) allow visual observation of debris accumulation on the strainer, and (2) modify the introduction of debris to better represent expected plant conditions. Specifically, the fiber was added upstream of the sump pit and allowed to be carried by the flow stream into the pit. In this test, all of the fiber attached to the top hats (no fiber was seen on the bottom of the sump pit or the bottom of the larger test tank). The inside surface of the top hats were observed to be about 50% clean, while the outside surfaces were about 15% clean, with the top hats on the "upstream" side of the pit collecting the most debris. This second test confirmed that substantial clean screen area is preserved with the entire fiber debris load collected on the top hats.

The final head loss during the chemical effects head loss test, after system stabilization was <0.10 ft.

The following flow chart, taken from Enclosure 3 of the NRC's Content Guidance for Chemical Effect, dated September 27, 2007 (Reference 71), identifies the steps and processes taken in the CR3 chemical effects analysis.



(1) Sufficient 'Clean' Strainer Area

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

CR3 did not perform a simplified chemical effects analysis (although testing has demonstrated that substantial clean screen area does exist).

(2) Debris Bed Formation

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

The bounding break for the CR3 head loss analysis and test is a double-ended hot leg break in the North D-Ring. This break location and size results in the greatest amount of fibrous debris generated, the greatest amount of particulate debris generated, the greatest amount of debris that transports to the sump strainers, and the highest recirculation flow rate. Other breaks may generate a slightly greater mass of chemical precipitates, but the debris bed would be smaller, resulting in an even greater clean screen area for the precipitates to pass through. Therefore, the selected break location is expected to yield the maximum head loss.

(3) Plant-Specific Materials and Buffers

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

Plant-specific inputs and assumptions used to determine chemical effects loading include the following:

- The post-LOCA containment recirculation pool and atmosphere temperature profiles are based on the CR3 containment analysis for a double-ended hot leg break (Reference 60).
- The pH profile of the sump pool is based on the maximum-pH case in the plant pH calculation (Reference 66). This calculation only determined the maximum pH (no time-based profile); therefore, the maximum pH (8.017) was used for the entire duration of the event.
- Prior to recirculation, pH of the containment spray is based on non-buffered borated water (pH = 4.5). Following transfer to recirculation, pH of the containment spray is based on the containment recirculation pool pH (8.017).
- The submerged aluminum is 525 lb/373 ft^2 and the unsubmerged aluminum is 3975 lb/2824 ft^2. All aluminum components which are not submerged are assumed to be wetted by containment spray. This is a conservative assumption, as much of the aluminum is within enclosures or sheltered from spray by intervening floors.
- The debris quantities in the recirculation pool are based on the debris generation calculation.
- The exposed area of concrete is 1809.6 ft^2, which bounds the break ZOI for qualified coatings.
- The recirculation pool volume is the maximum calculated in the RB flood level calculation (Reference 15), which results in the greatest quantities of chemical precipitates.
- The sump pool is assumed to be mixed after 13 hours. This allows for approximately 12 turnovers of the sump volume.

The materials considered in the chemical formation evaluation are consistent with the guidance of WCAP-16530-NP, and its supporting spreadsheet. For CR3, the contributing materials for the bounding LBLOCA include NUKON insulation, metallic aluminum (submerged and sprayed), aluminum paint, and concrete. The resulting chemical precipitates include sodium aluminum silicate, aluminum oxyhydroxide, and calcium phosphate.

(4) Approach to Determine Chemical Source Term

- ***Licensees should identify the vendor who performed plant-specific chemical effects testing.***

Head loss testing, with chemicals, was performed by Alion Science and Technology at their Warrenville, Illinois test facility.

(5) Separate Effects Decision (Decision Point)

- ***State which method of addressing plant-specific chemical effects is used.***

CR3 testing used the methods presented in WCAP-16530-NP (Reference 67) and WCAP-16785-NP (Reference 68) to determine the quantity of precipitates to be used. The only plant-specific refinement adopted from WCAP-16785 was phosphate inhibition of aluminum corrosion.

(6) AECL Model

- ***Since the NRC staff is not currently aware of the testing approach, the NRC staff expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results.***
- ***Licensees should provide the chemical identities and amounts of predicted plant-specific precipitates.***

CR3 does not use the AECL model.

(7) WCAP Base Model

- ***For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart, justify any deviations from the WCAP base model spreadsheet (i.e., any plant-specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.***
- ***List the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.***

The CR3 chemical effects evaluation process does not proceed from block 7 to block 10 in the Figure 1 flowchart, as refinements were made in accordance with WCAP-16785-NP.

The types and amounts of predicted precipitates at CR3 are:

Precipitate	WCAP-16530-NP Mass (lbm)	WCAP-16785-NP Mass (lbm)
Sodium Aluminum Silicate	47.5	47.5
Aluminum Oxyhydroxide	38.1	25.1
Calcium Phosphate	3.1	3.1

Crediting phosphate inhibition of aluminum corrosion resulted in a 13 lb decrease in Aluminum Oxyhydroxide.

Chemical effects head loss testing was performed based on the results of a draft chemical product formation report. Subsequent to the testing, non-conservatisms were identified in the draft calculation. The following table identifies the amount of chemicals predicted to form in the draft calculation:

Precipitate	Mass (lbm)
Sodium Aluminum Silicate	38.8
Aluminum Oxyhydroxide	18.0
Calcium Phosphate	3.1

Although the tested quantity of precipitates are non-conservative compared to the final predicted amounts of precipitates, the test demonstrated that the chemical precipitates have a negligible effect on sump screen head loss. This is due to substantial clean screen area remaining after the addition of all other debris. To verify the presence a of clean screen area with the amount of debris expected to reach the screen, a confirmatory test was performed with fiber only. This test was designed to facilitate visual confirmation of screen coverage. Pictures of the resulting screen coverage and clean area are included in Enclosure 6.

(8) WCAP Refinements

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

CR3 refined the WCAP-16530-NP model to credit phosphate inhibition in accordance with Item 3 in Section 6 of WCAP-16785-NP and implementation guidance contained in PWROG letter OG-07-373 (Reference 70). The resulting chemical precipitates are shown in the response to question (7) above.

(9) Solubility of Phosphates, Silicates, and Al Alloys

- ***Licensees should clearly identify any refinements (plant-specific inputs) to the base WCAP-16530 model and justify why the plant-specific refinement is valid.***
- ***For crediting inhibition of aluminium that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminium, (2) the time needed to reach a phosphate or silica level in the pool that would result in aluminium passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminium that is sprayed is assumed to be passivated.***
- ***For any attempt to credit solubility (including performing integrated testing), licensees should provide the technical basis that supports extrapolating solubility test data to plant-specific conditions. In addition, licensees should indicate why the overall chemical effects evaluation remains conservative when crediting solubility given that small amounts of chemical precipitate can produce significant increases in head loss.***
- ***Licensees should list the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.***

CR3 refined the WCAP-16530-NP model to credit phosphate inhibition in accordance with Item 3 in Section 6 of WCAP-16785-NP and implementation guidance contained in PWROG letter OG-07-373 (Reference 70). Since CR3 uses trisodium phosphate as a buffer, and is therefore assured to have an abundance of phosphate in solution, crediting the phosphate inhibition of aluminum is reasonable. However, as the CR3 head loss testing has demonstrated, the quantity of chemical precipitates does not affect the head loss across the sump strainer, as substantial clean screen area exists.

No additional credit for inhibition or solubility limits was taken.

See section (7) for predicted amounts of chemical precipitates.

(10) Precipitate Generation (Decision Point)

- ***State whether precipitates were formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.***

Chemical precipitates used in testing were formed in a separate mixing tank in accordance with WCAP-16530-NP and subsequently introduced into the test loop.

(11) Chemical injection into the Loop

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

- ***For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminium), the percentage that precipitates, and the percentage that remains dissolved during testing.***
- ***Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100 percent 140 percent).***

CR3 testing did not use chemical injection into the test loop.

(12) Pre-mix in Tank

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

CR3 did not take any exceptions to the procedure recommended for surrogate precipitate formation in WCAP-16530.

(13) Technical Approach to Debris Transport (Decision Point)

- ***State whether or not near-field settlement is credited.***

No near-field settling is credited.

(14)and (14a) Integrated Head Loss Test with Near-Field Settlement Credit

- ***Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.***
- ***Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.***

No near-field settling is credited.

(15)and (15a) Head Loss Testing without Near Field Settlement

- ***Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.***
- ***Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).***

During the chemical effects head loss test, debris was added to the test tank directly over the "sump pit." This was intended to ensure that all debris was in the pit (not on the tank floor) and therefore had a good opportunity to attach to the top hat surface. During this test, water clarity never improved to the point where an assessment could be made regarding debris accumulation on the strainer versus settling in low turbulence zones within the sump pit (the lack of clarity is attributed to a clean screen area, such that the debris bed could not filter out all of the particulates and precipitates). However, when the tank was drained, some amount of fiber was found on the floor of the sump pit in the immediate vicinity of the top hats, as well as some paint chips on horizontal surfaces. Also, as expected, a significant amount of precipitates was found on the floor of the sump pit and tank, as the precipitates remained in solution for the entire test.

A subsequent test was performed where only the fiber was added to the tank. This test was performed to: (1) allow visual observation of debris accumulation on the strainer, and (2) modify the introduction of debris to better represent expected plant conditions. Specifically, the fiber was added upstream of the sump pit and allowed to be carried by the flow stream into the pit. In this test, all of the fiber attached to the top hats (no fiber was seen on the bottom of the sump pit or the bottom of the larger test tank). The inside surface of the top hats were observed to be about 50% clean, while the outside surfaces were about 15% clean, with the top hats on the "upstream" side of the pit collecting the most debris. This second test confirmed that a substantial clean screen area is preserved with the entire fiber debris load collected on the top hats.

The one-hour precipitate settlement values and timing relative to start of testing are included in the following tables:

Aluminum Oxyhydroxide Precipitate Settlement Values

Batch	Settled Volume (mL)	Time from Date Tested to Date Used (days)
AlO17	8.4	17
AlO18	8.4	17
AlO19	7.5	17
AlO20	9.0	17
AlO21	8.6	5
AlO22	6.6	5
AlO23	8.1	5
AlO24	6.3	3
AlO25	6.0	3
AlO26	8.2	3
AlO27	8.8	3

Calcium Phosphate Precipitate Settlement Values

Batch	Settled Volume (mL)	Time from Date Tested to Date Used (days)
Ca10	6.7	17
Ca11	5.1	12

Sodium Aluminum Silicate Precipitate Settlement Values

Batch	Settled Volume (mL)	Time from Date Tested to Date Used (days)
Na235	9.0	17
Na238	9.1	17
Na239	9.0	17
Na240	9.1	12
Na241	8.5	12
Na242	9.5	12
Na243	8.5	12
Na244	8.5	12
Na245	8.0	12
Na246	7.0	7
Na247	8.0	7

It is recognized that the guidance of PWR Owners Group letter OG-07-408 was not met regarding settling rate measurements within 24 hours of use in the test loop. However, the letter does acknowledge the following observations regarding settling rates:

- Testing performed by Pacific Gas and Electric Company (PG&E) showed that the settling rate and filtration properties of the sodium aluminum silicate surrogate were essentially constant over time.

- The PG&E testing also showed that, although the settled volume of the aluminum oxyhydroxide surrogate slowly decreased over time, the head loss caused by the surrogate material increased over time, and thus head loss testing performed using the surrogate material was conservative.

There is no information in the letter regarding the change of calcium phosphate settling rates over time. However, based on the configuration of the test apparatus, including the use of a sparger at the bottom of the test tank to induce turbulence and prevent settling of debris and precipitates, and especially the existence of a clean screen area on the strainers, the relevance of settling rates is minimal.

(16) Test Termination Criteria

- ***Provide the test termination criteria.***

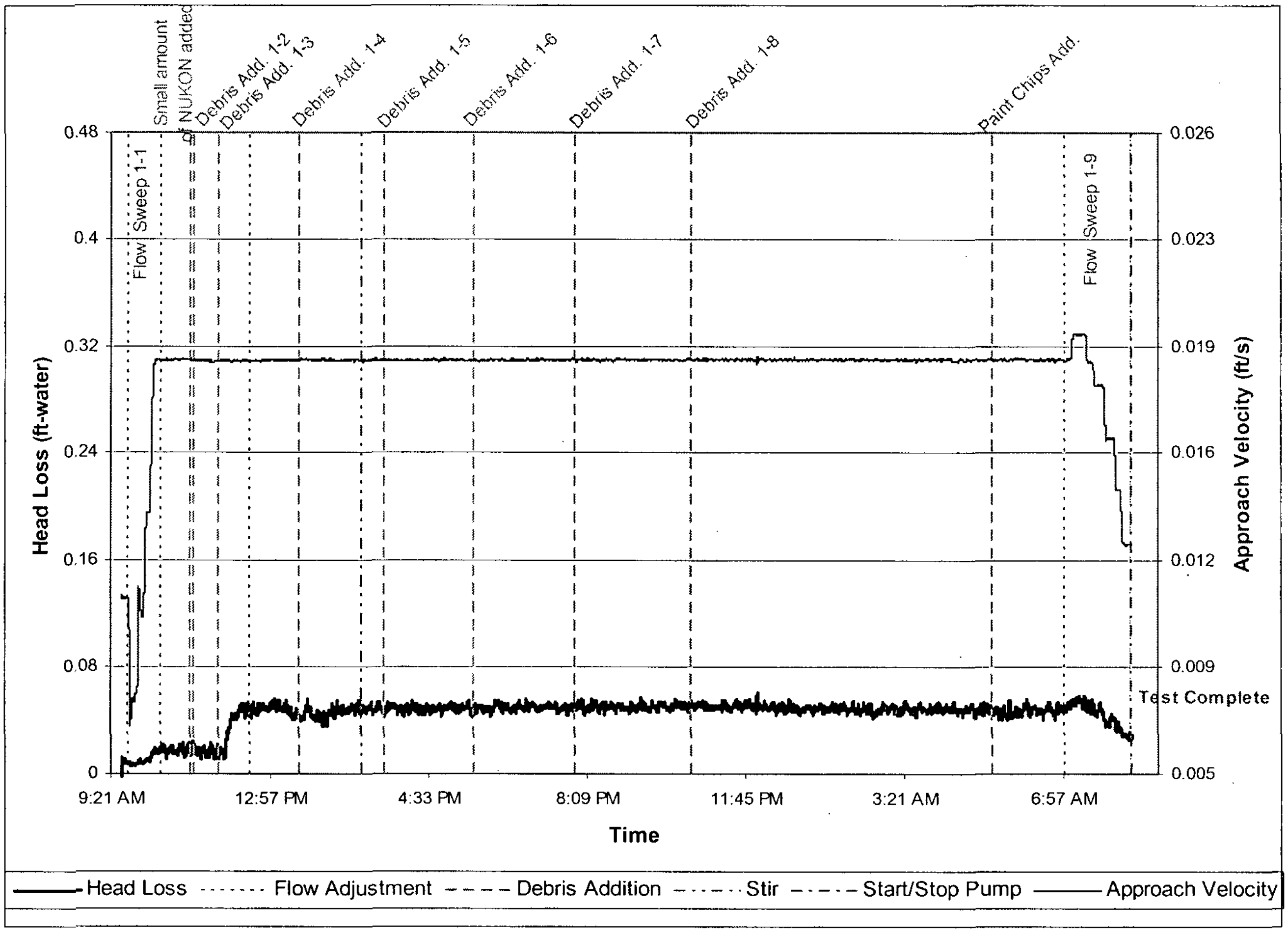
The termination criteria for the head loss testing were:

- At least five pool turnovers have occurred, and
- The differential pressure across the debris bed changes by less than or equal to 1% over a one-hour period.

(17) Data Analysis

- ***Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.***
- ***Licensees should explain any extrapolation methods used for data analysis.***

The pressure drop curve from the chemical effects test:



Although the final calculated amount of chemical precipitates exceeds the tested amount as discussed in previous sections, no extrapolation of data was needed due to the shape of the head loss curve (i.e., flat).

(18) Integral Generation (Alion)

- ***State whether integrated testing performed by Alion is credited.***

Integrated testing is not credited.

(19) Tank Scaling/Bed Formation

- ***Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values.***
- ***Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.***

Not applicable, as integrated testing was not performed.

(20) Tank transport

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

Not applicable, as integrated testing was not performed.

(21) 30-day Integrated Head Loss Test

- ***Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.***
- ***Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.***

CR3 did not perform a 30-day integrated head loss test.

(22) Data Analysis Bump Up Factor

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

Not applicable, as integrated testing was not performed.

p. 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.

Changes to the CR3 licensing basis will be implemented in accordance with the requirements of 10 CFR 50.59 consistent with the extensions approved by the NRC in a letter dated December 30, 2007. The FSAR will be updated in accordance with the requirements of 10 CFR 50.71(e), to reflect changes made due to the sump evaluation or plant modifications required to resolve GSI-191. CR3 does not anticipate requiring NRC staff review for the remaining corrective action (removal of fibrous insulation) planned for full compliance with GSI-191. Additionally, CR3 does not anticipate making changes to the ITS. Therefore, there are no plans to submit a License Amendment Request to close GSI-191. The current licensing basis, which assumes a maximum sump screen blockage of 50%, will be maintained until the remaining corrective action is complete.

References

1. NRC GSI-191, "Assessment of Debris Accumulation on PWR Sump Performance," prioritized September, 1996
2. NRC GL 2004-02, "Potential Impact of Debris Blockage of Emergency Recirculation During design basis Accidents at Pressurized-Water Reactors," dated September 13, 2004
3. GSI-191 SE, Revision 0, "Safety Evaluation of NEI Guidance on PWR Sump Performances," dated December 6, 2004
4. NRC Audit Report, "Report on Results of Staff Pilot Plant Audit – Crystal River Analyses Required for the Response to Generic Letter 2004-02 and GSI-191 Resolution." dated June 29, 2008
5. NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors," dated June 9, 2003
6. NRC Regulatory Guide (RG) 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps," dated November 2, 1970
7. NRC Regulatory Guide (RG) 1.82, Revision 3, "Water Sources for Long-Term Recirculation Cooling following a Loss-of-Coolant Accident," dated November 2003
8. NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments" Revision 1, dated September 2002
9. NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Volume 1 – "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, December 2004 and subsequent NRC SER (Volume 2)
10. WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 0
11. CR3 Engineering Change (EC) 58982, "Reactor Building Sump Strainer, RB Flow Distributor, and RB Debris Interception Modifications"
12. CR3 Engineering Change (EC) 59476, "RB Sump Level Indication Modification"
13. Progress Energy PE&RAS-05-008, "Response to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," dated March 4, 2005
14. CR3 Calculation M90-0021, Revision 14, "Building Spray and Decay Heat Pump $NPSH_{a/r}$"
15. CR3 Calculation M90-0023, Revision 11, "Reactor Building Flooding"
16. Framatome document 77-5036736-00 "Debris Source Inventory Walkdown Report," Revision 0, dated December 16, 2003
17. CR3 Calculation M04-0004, Revision 2, "CR3 Reactor Building GSI 191 Debris Generation Calculation"
18. CR3 Calculation M04-0005, Revision 2, "CR3 Reactor Building GSI-191 Debris Transport Calculation"
19. CR3 Calculation M04-0006, Revision 1, "CR3 RB LOCA Pool CFD Transport Analysis." (this was incorporated into M04-0005 as part of revision 2 to that calc)
20. CR3 Calculation M04-0007, Revision 1, "CR3 RB Sump Head Loss Calculation for Debris Laden Screen"
21. CR3 Calculation M04-0016, Revision 0, "RB Sump Screen – Downstream Effects Evaluation"
22. CR3 Calculation M04-0019, Revision 1, "RB Sump Screen – Clean Sump Screen Head Loss, Surface Area, Interstitial Volume"
23. Engineering Changes 48755, Revision 5, CR3 Cycle 14 and 15 Reload Core Design and Safety Analyses
24. CR3 Calculation M95-0009, Revision 1, "CR3 Sump Solution pH Calculation – Report"
25. CR3 Engineering Evaluation EEM98-001, Revision 1, "MU/HPI Pump Qualification"
26. Test Plan: Characterization of Chemical and Corrosion Effects Potentially Occurring inside a PWR Containment Following a LOCA," Westinghouse, EPRI, NRC, dated July 20, 2005
27. CR3 Calculation M85-1004, Revision 4, "Hydrogen Generation"
28. CR3 Calculation S89-0050, Revision 10, "Unqualified Coatings Log"
29. WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Westinghouse Owner's Group, August 2007
30. NUREG/CR-6885, LA-UR-04-5416, Screen Penetration Test Report, October 2005
31. CR3 Calculation S04-0006, Revision 0, "RB Sump Strainer Structural Design"
32. CR3 Calculation S04-0007, Revision 0, "RB Sump Trash Rack Structural Design"
33. CR3 Calculation S04-0008, Revision 0, "RB Flow Distributor, Debris Interceptor, and Fuel Transfer Canal Drain Trash Rack Structural Design"

34. CR3 Topical Design Basis Document (TDBD) Tab 9/5, Revision 5, "High Energy Line Breaks Inside Containment"
35. NRC GL 87-11, "Relaxation in Arbitrary Intermediate Pipe Rupture Requirements"
36. CR3 Drawing 304-818, Revision 1, "High Energy Line Breaks Locations and Pipe Whip/Jet Impingement Zones – Inside Containment"
37. NRC GL 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps"
38. 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"
39. Progress Energy Procedure EGR-NGGC-0005, Revision 27, "Engineering Change"
40. CR3 Procedure SP-324, Revision 56, "Containment Inspection"
41. MNT-NGGC-0007, Revision 6, "Foreign Material Exclusion Program"
42. CPL-XXXX-W-005, Revision 11, "Specification for Nuclear Power Plant Protective Coatings"
43. CR3 Procedure SP-175A, Revision 0, "Reactor Building Emergency Sump Inspection"
44. CR3 Procedure AI-516, Revision 5, "Plant Labeling Guidelines"
45. CR3 Procedure AI-607, Revision 22, "Pre-Job and Post-Job Briefings"
46. CR3 Calculation M98-0123, Revision 4, "CR3 HPI Hydraulic Analysis (Post 11R modifications to MU System)"
47. CR3 Calculation M96-0020, Revision 0, "Decay Heat Drop Line Maximum Flow and Velocity Analysis"
48. CR3 Calculation M97-0008, Revision 0, "Evaluation of BWST Draining for Appendix R Issue"
49. NRC Bulletin No. 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers"
50. NGG Procedure EGR-NGGC-0351, Revision 14, "Condition Monitoring of Structures"
51. CR3 Letter No. 3F1198-02, "Response to Generic Letter 98-04"
52. WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings," June 2006
53. CR3 Specification SP-5953, Insulation, Dated 12/13/71
54. CR3 Engineering Change (EC) 65264, Modify/Replace Cyclone Separator and Replace Seal on DHP-1B
55. CR3 Engineering Change (EC) 65882, Modify/Replace Cyclone Separator on DHP-1A
56. CR3 Engineering Change (EC) 65883, Modify/Replace Cyclone Separator on BSP-1A
57. CR3 Engineering Change (EC) 65884, Modify/Replace Cyclone Separator on BSP-1B
58. CR3 Engineering Change (EC)-ED 68809, Evaluation of RB Sump Backwashing Methods
59. Alion Report ALION-REP-ENER-4724-02, "Crystal River 3 Chemical Product Formation Report," Rev. 0
60. CR3 Calculation M97-0132, Revision 7, "CR3 Containment Analysis"
61. CR3 Emergency Operating Procedure EOP-14, Enclosure 19, "ECCS Suction Transfer," Rev. 20
62. CR3 Improved Technical Specifications Through License Amendment No. 228
63. AREVA Report 51-9031119-000, "GSI-191 Downstream Effects Evaluation for CR3"
64. AREVA Report 51-5065265-00, "Summary of Blade-to-Blade Gaps of FUELGUARD Grid Designs"
65. Alion Report ALION-REP-LAB-2352-77, "Erosion Testing of Low Density Fiberglass Insulation," Rev. 1
66. CR3 Calculation M95-0009, Revision 1, "CR3 Sump Solution pH Calculation"
67. WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," Rev. 0
68. WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model," Rev. 0
69. Alion Report ALION-REP-ENER-4724-07, "Head Loss Testing of a Prototypical Crystal River 3 Nuclear Plant Top-Hat Strainer Array," Draft Revision 0A
70. PWROG letter OG-07-373, Chemical Effects Spreadsheet Refinements - Refined Guidance Regarding Solubility Limits (PA-SEE-0354), August 20, 2007
71. CR3 to NRC letter dated December 10, 2007, "Crystal River Unit 3 – Request for Extension of Completion Date for Corrective Actions and Modifications Required by Generic letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors'"
72. NRC to CR3 letter dated December 28, 2007, "Crystal River Unit 3 – Generic letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors,' Extension request Approval"

73. CR3 Engineering Change (EC)-ED 62266, HP Auxiliary Pressurizer Spray: Initial DHV-126 EOP Positioning
74. Alion Report ALION-REP-ENER-4724-06, "Bypass Debris Characterization Report for Crystal River 3 Nuclear Plant," Draft Revision 0C

Enclosures

1. Schematic of CR3 LPI (DH) and CS (BS) Systems
2. General Containment Layout at CR3
3. CR3 Design Basis Break Locations
4. CR3 Pool Velocity Vectors above RB Floor
5. CR3 Sump Sketches
6. Photos

Enclosure 1

Schematic of CR3 LPI (DH) and CS (BS) Systems

To MUP's (piggy-back to DHP's)

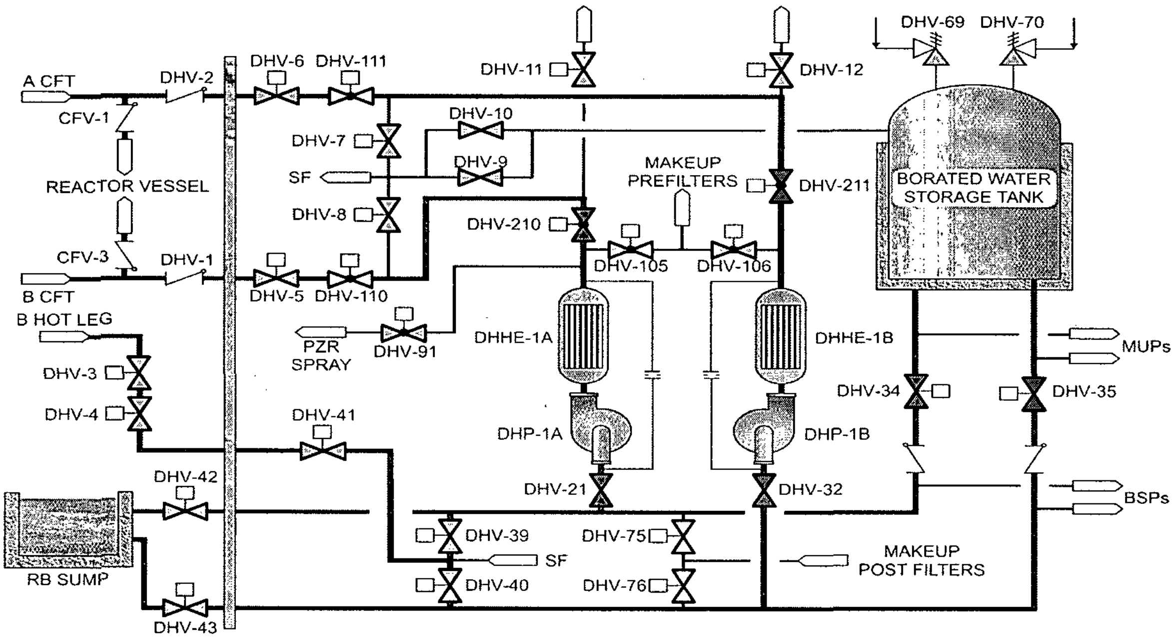
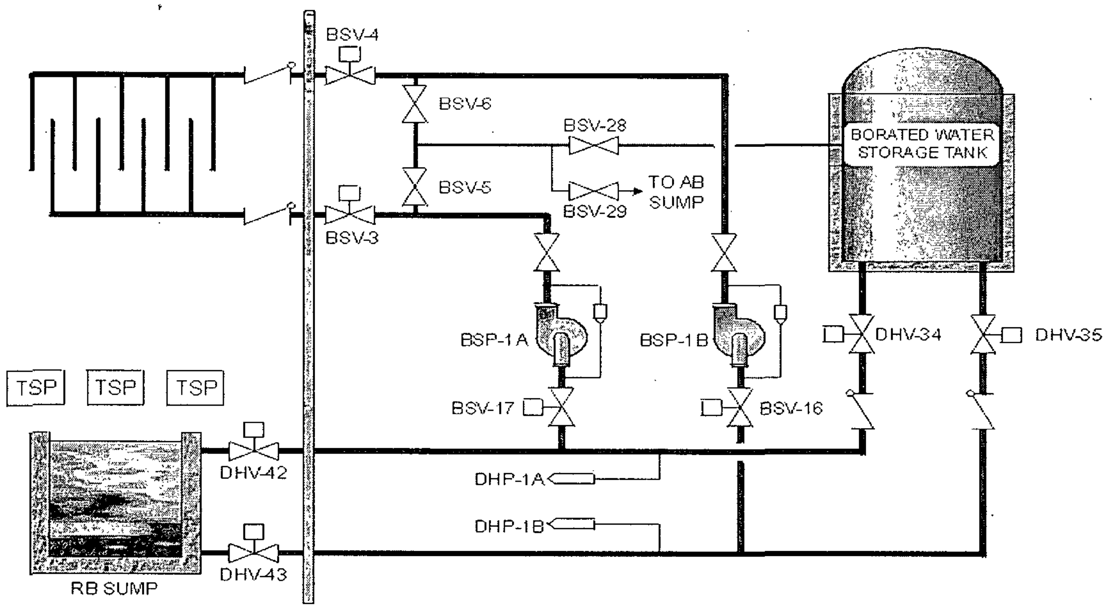


FIGURE 1 - REV 1 - DECAY HEAT REMOVAL SYSTEM



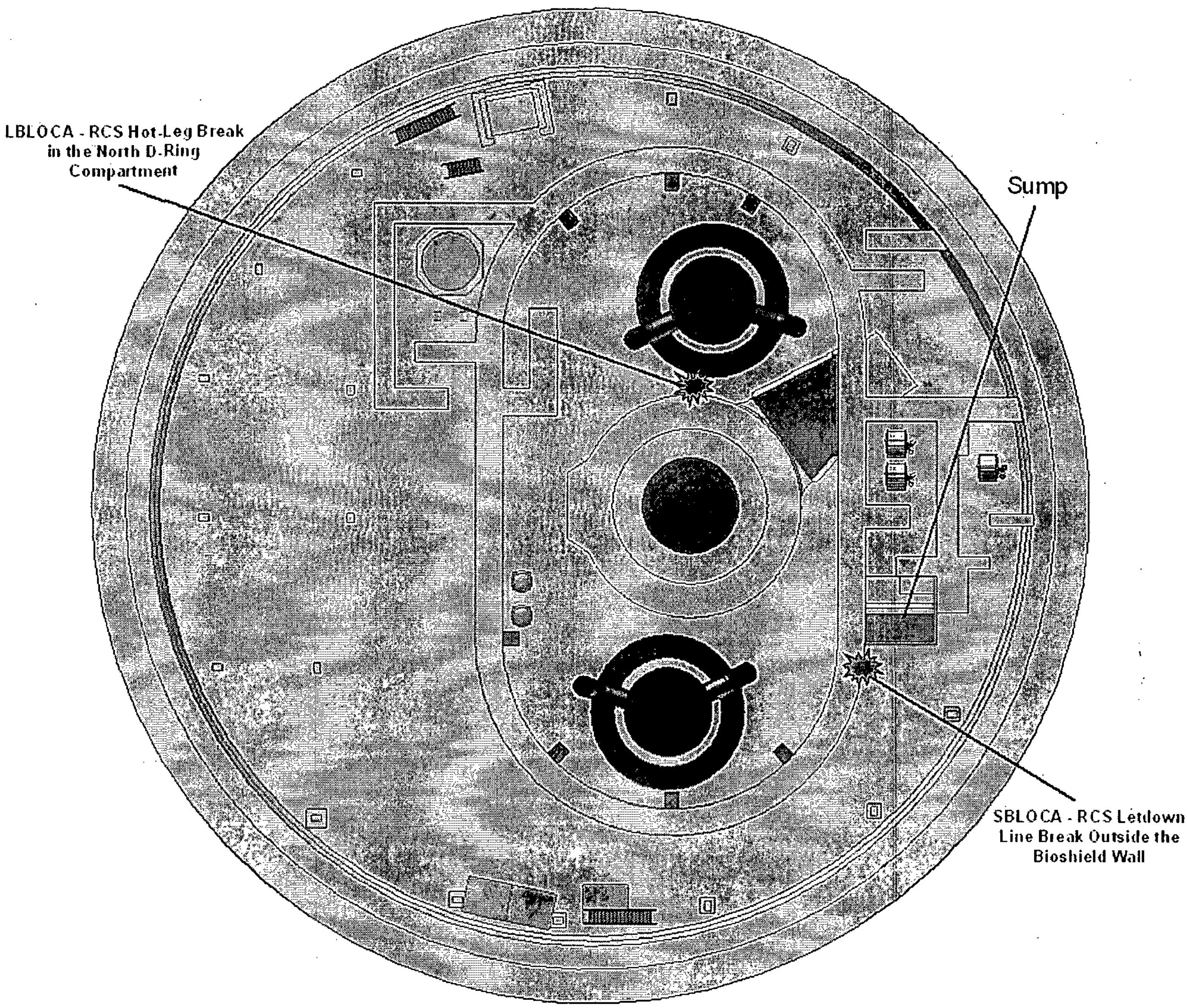
CR3 BS System

Enclosure 2

General Containment Layout at CR3 (RB Sump on East Side, North is up)

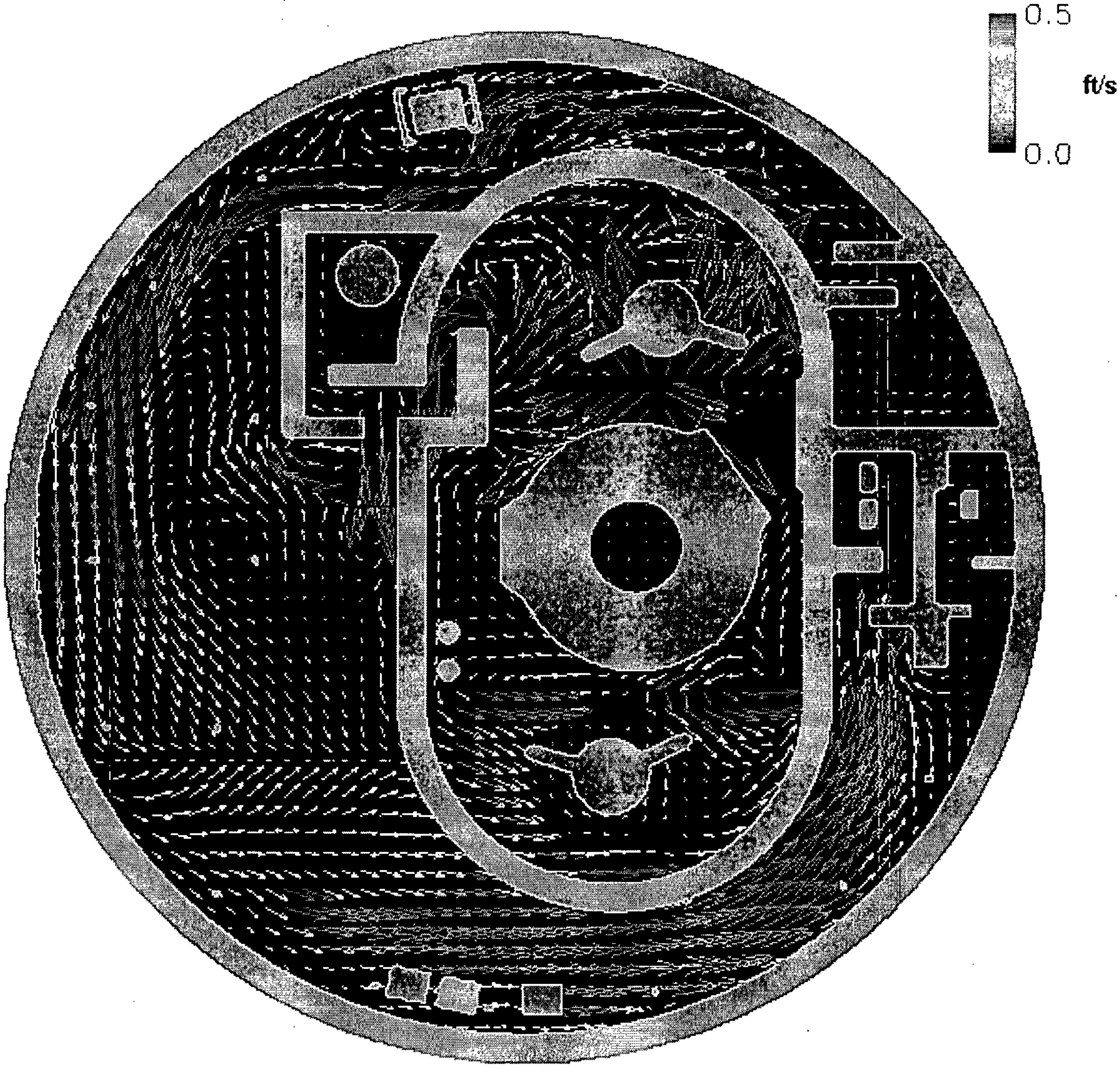
Enclosure 3

CR3 Design Basis Break Locations



Enclosure 4

CR3 Pool Velocity Vectors above RB Floor
(Diverter and Interceptor shown)



Enclosure 5
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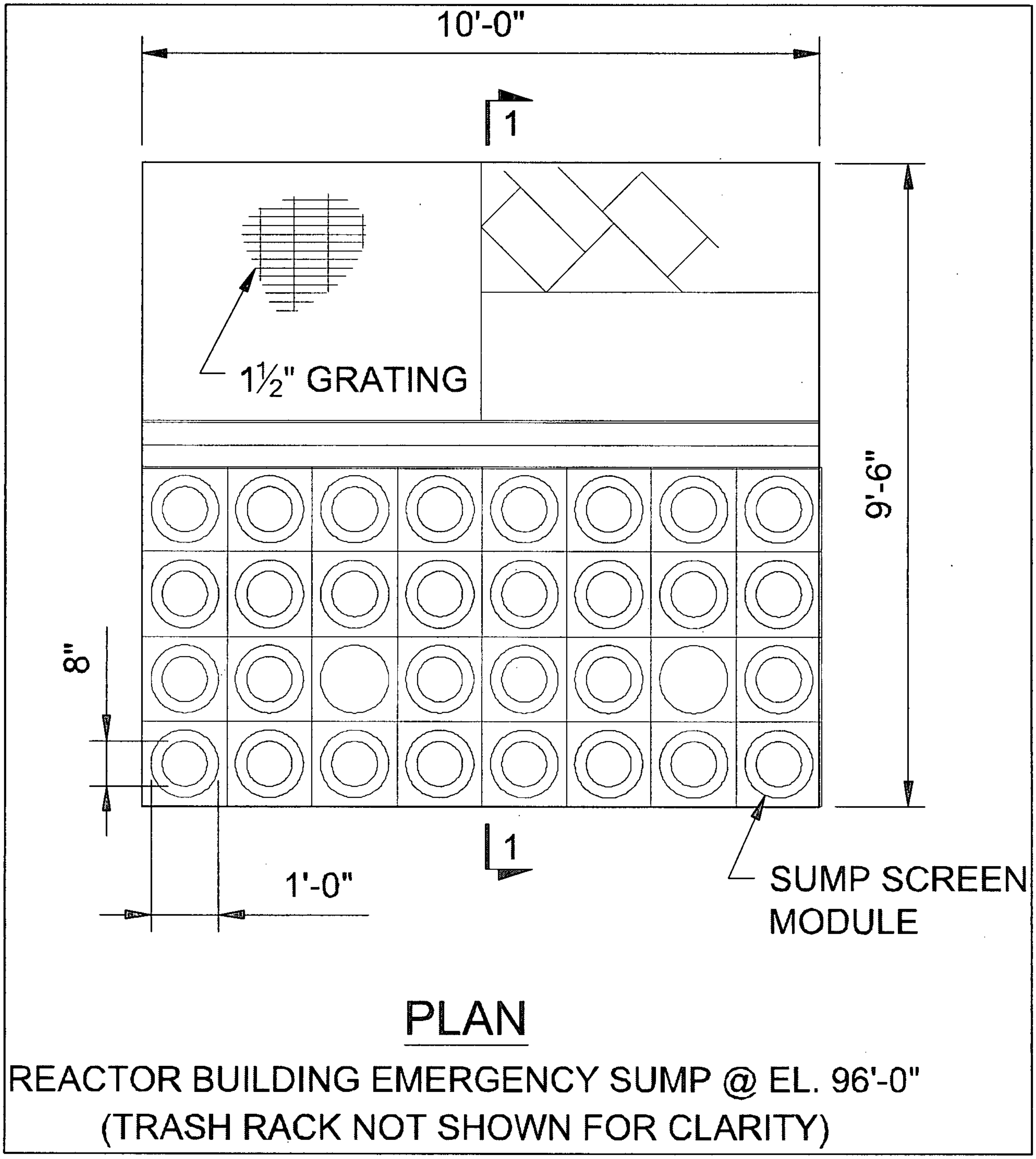
CR3 RB Sump
Plan View



Enclosure 5
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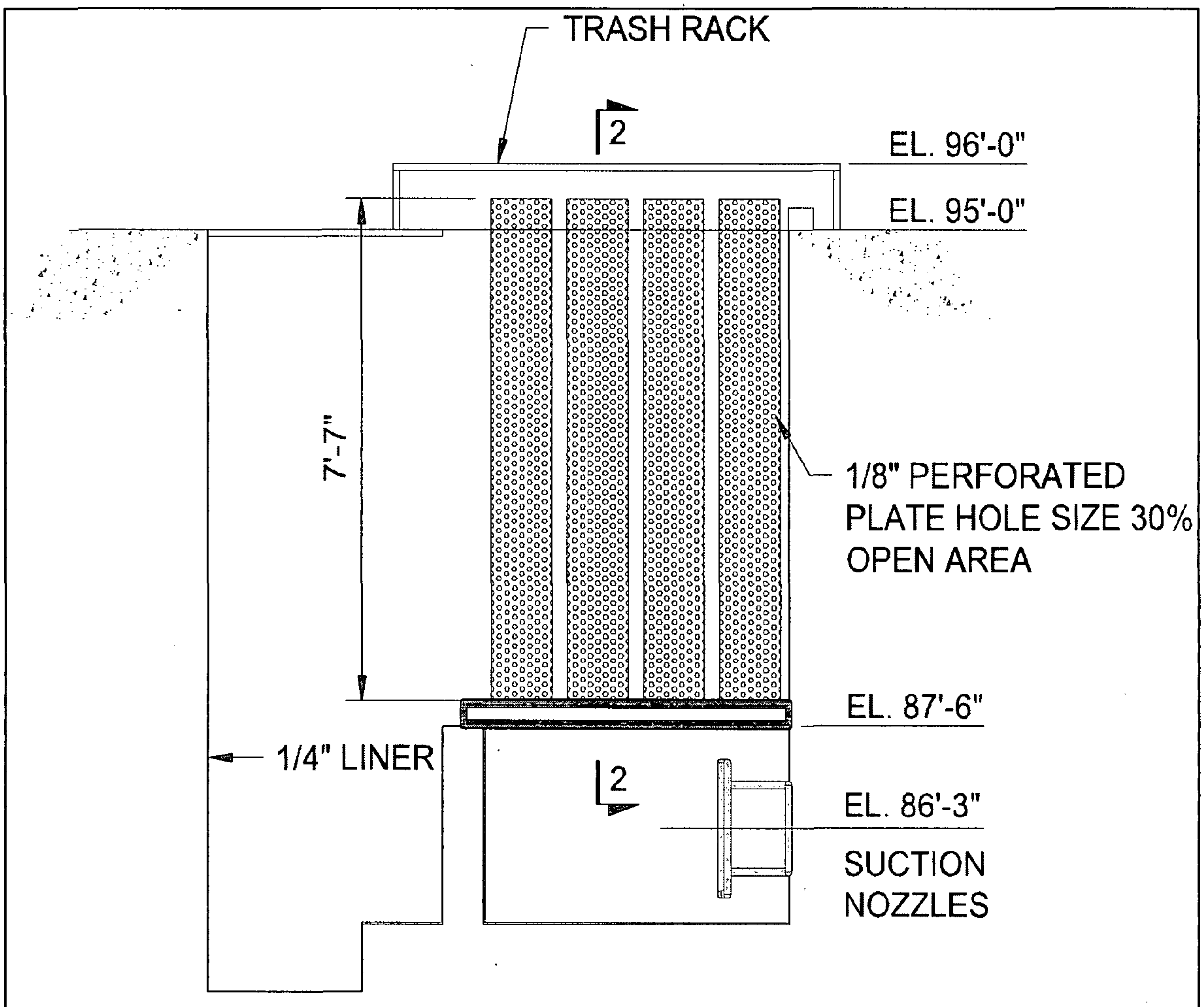
CR3 RB Sump
Elevation View



SECTION 1-1

Enclosure 6
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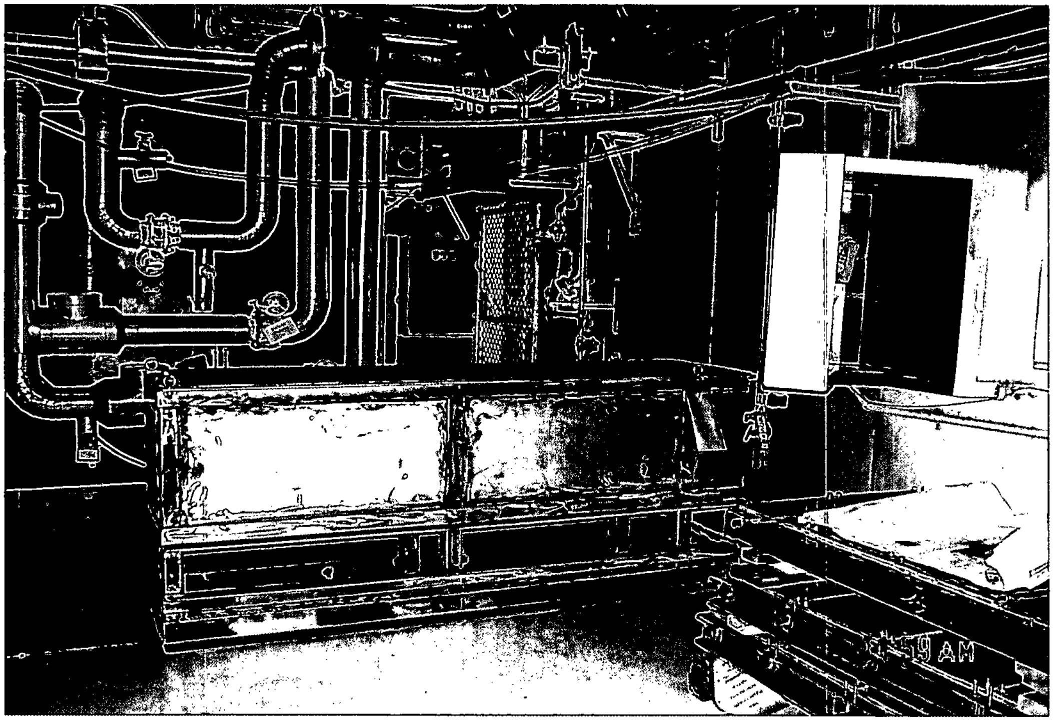
Photos

1. CR3 Flow Distributor
2. CR3 Debris Interceptor
3. CR3 Scupper Cover
4. CR3 Fuel Transfer Canal Drain Strainer
5. CR3 Sump Strainer
6. CR3 Sump Trash Rack
7. CR3 Sump Strainer and Trash Rack (looking down from above)
8. CR3 Sump Strainer and Trash Rack (looking up from below)
9. CS Suction Line in Sump (bellmouth flanged)
10. CR3 Sump Level and Strainer dP Sensor
11. CR3 Test Picture – Debris Loading (Fiber-Only Test)
12. CR3 Test Picture – Test Array Following Draining (Full Debris/Chemical Test)

Enclosure 6
(page 2 of 7)



Picture 1. CR3 Flow Distributor

Picture 2. CR3 Debris Interceptor

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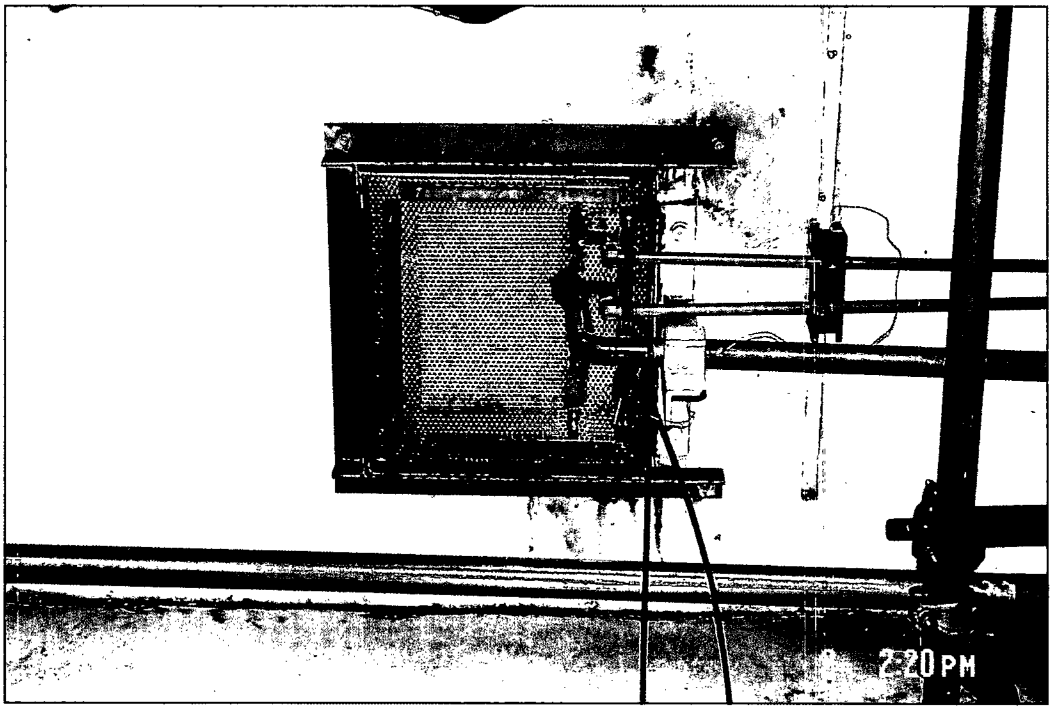
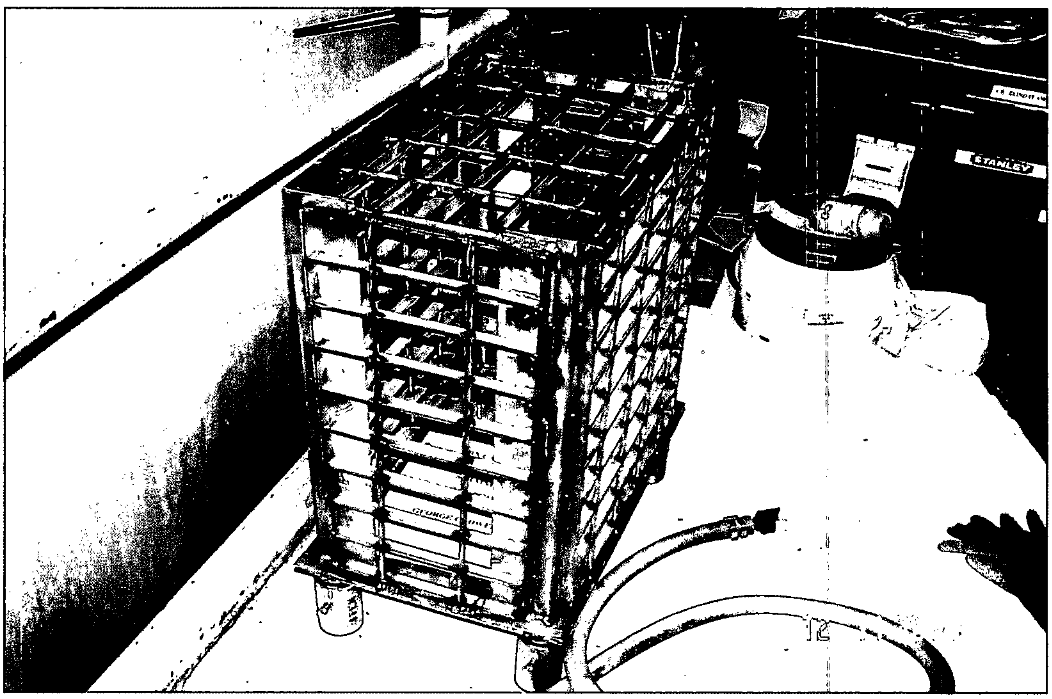


Picture 3. CR3 Scupper Cover



Picture 4. CR3 Fuel Transfer Canal Drain Strainer (standby for installation)

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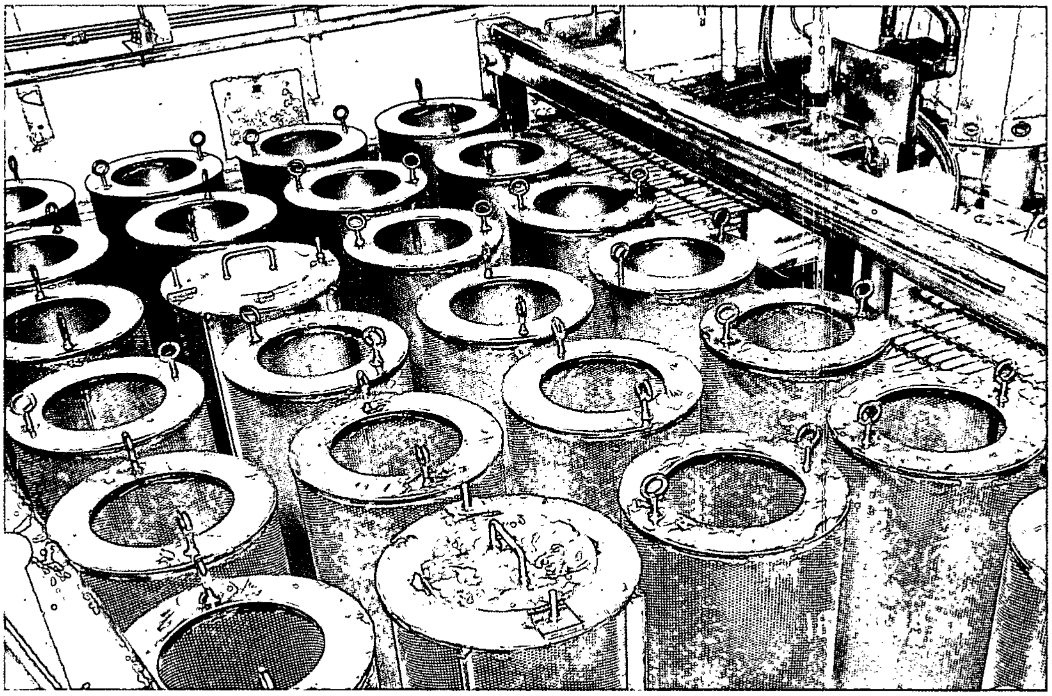
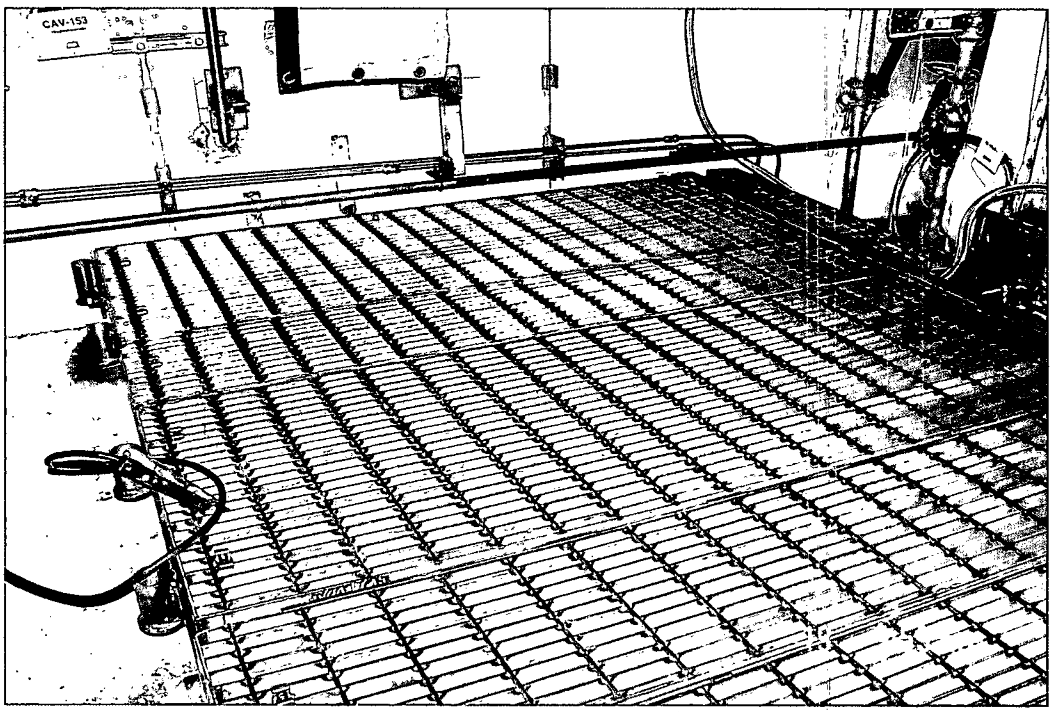


Picture 5. CR3 Sump Strainer (top hat assembly, during assembly)



Picture 6. CR3 Sump Trash Rack (during assembly)

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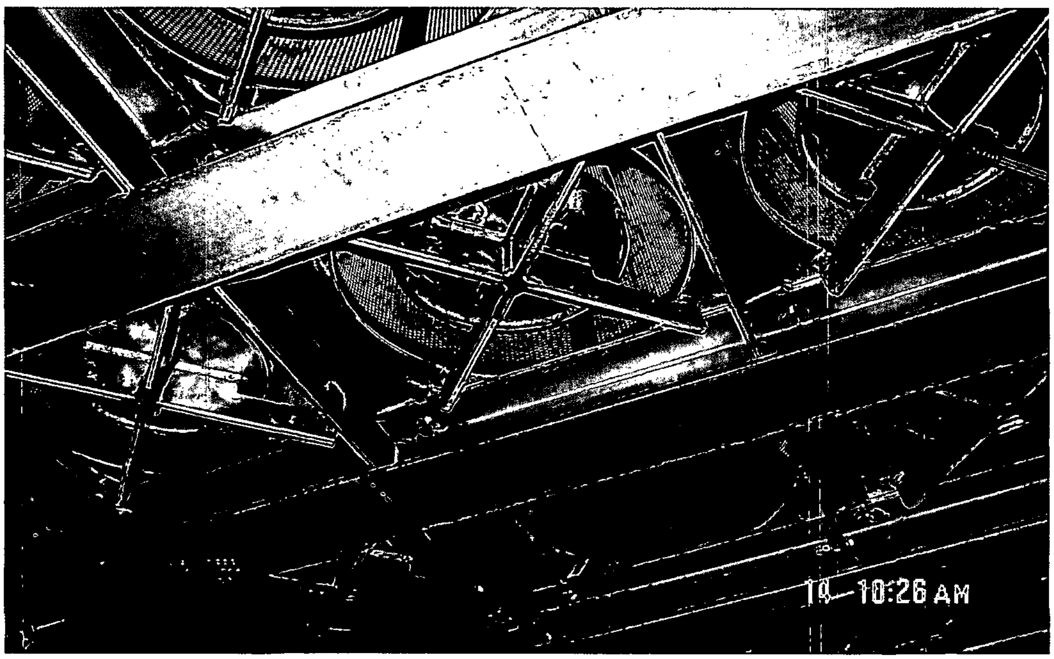
Picture 7. CR3 Sump Strainer and Trash Rack (looking down from above)



Picture 8. CR3 Sump Strainer and Trash Rack (looking up from below)

Enclosure 6
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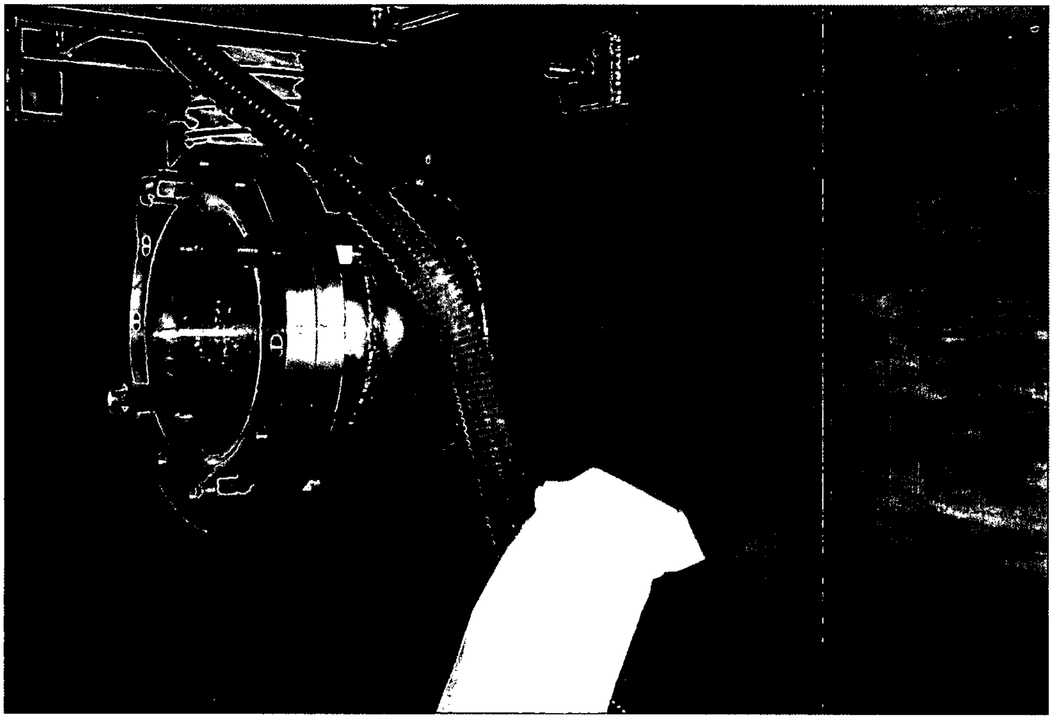
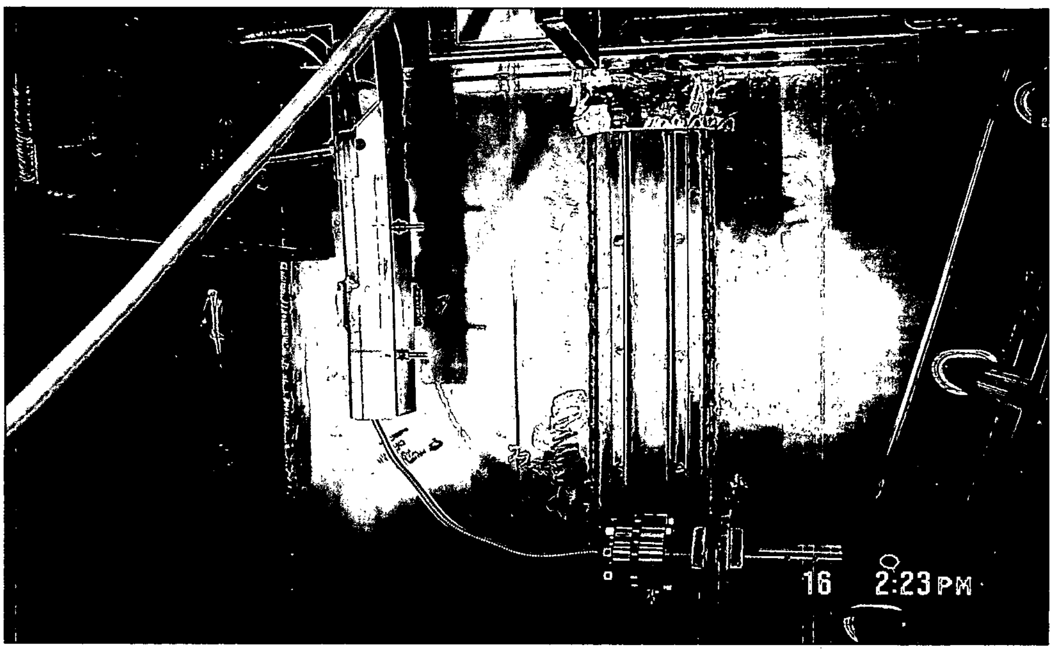


Picture 9. CS Suction Line in Sump (bellmouth flanged)



Picture 10. CR3 Sump Level and Strainer dP Sensor

Enclosure 6
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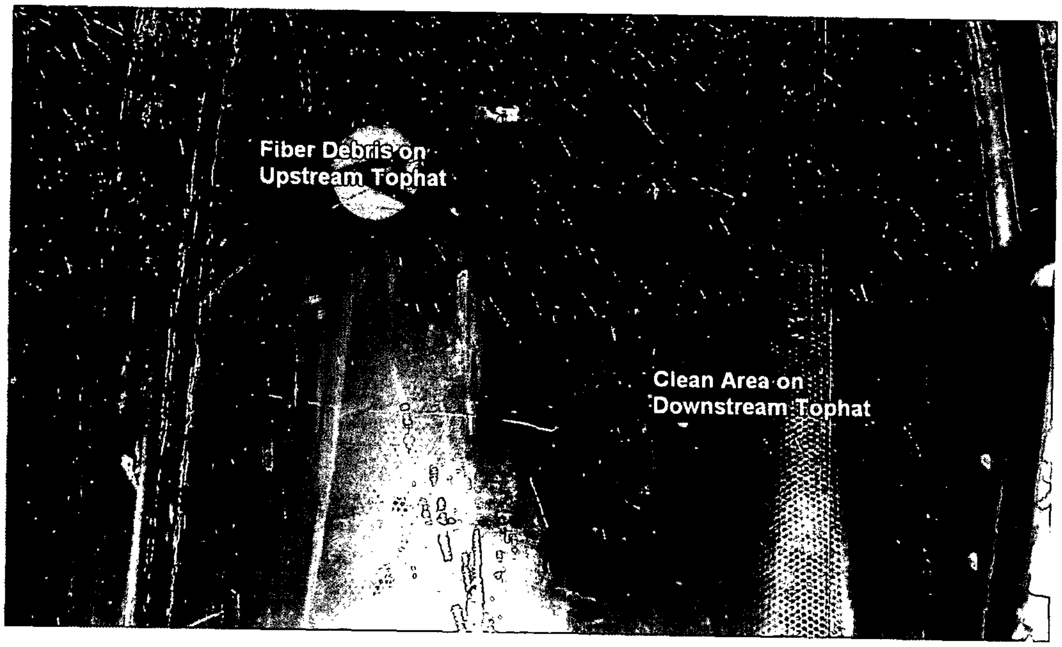
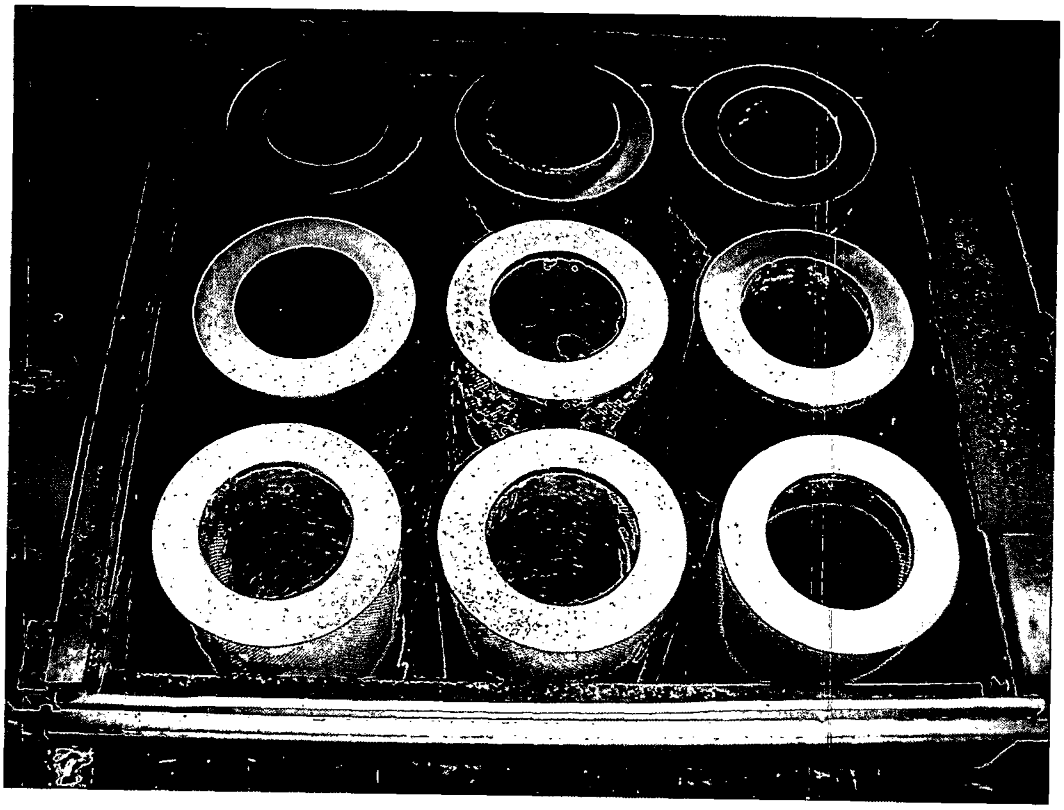


Picture 11. Debris Loading (Fiber-only Test)



Picture 12. Test Array Following Tank Draining (Full debris/chemical test)