Nuclear Operating Company

South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

December 11, 2008
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10CFR50.54(f)

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
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Rockville, MD 20852

South Texas Project
Units 1 and 2
Docket Nos. STN 50-498 and STN 50-499
Supplement 4 to the Response to Generic Letter 2004-02
(TAC Nos. MC4719 and MC4720)

References:

1. Letter dated November 21, 2007, from William H. Ruland, NRC, to Anthony Pietrangelo, NEI, "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses" (ML073110269, ML073110278)
2. Letter dated December 13, 2007, from David W. Rencurrel, STPNOC, to NRC Document Control Desk, "Supplement to Request for Extension for Final Response to Generic Letter 2004-02 and Implementation of Revised Design Basis for ECCS Sump" (ML073580125, NOC-AE-07002249)
3. Letter dated December 19, 2007, from Mohan C. Thadani, NRC, to James J. Sheppard, STPNOC, "South Texas Project, Units 1 And 2 - Approval Of Extension Request For Corrective Actions Re: Generic Letter 2004-02, "Potential Impact Of Debris Blockage On Emergency Recirculation During Design Basis Accidents At Pressurized Water Reactors," (ML073520076, NOC-AE-08002316)
4. Letter dated February 29, 2008, from David W. Rencurrel, STPNOC, to NRC Document Control Desk, "Supplement 3 to the response to Generic Letter 2004-02," (ML08070038, NOC-AE-07002240)
5. Letter dated June 19, 2008, from Gerald T. Powell, STPNOC, to NRC Document Control Desk, "Request for Extension for Final Response to Generic Letter 2004-02 and Implementation of Revised Design Basis for ECCS Sump," (ML081780060, NOC-AE-08002316)
6. Letter dated July 2, 2008, from Mohan C. Thadani, NRC, to James J. Sheppard, STPNOC, "South Texas Project, Units 1 And 2 - Approval Of Extension Request For Corrective Actions Re: Generic Letter 2004-02, "Potential Impact Of Debris Blockage On Emergency Recirculation During Design Basis Accidents At Pressurized Water Reactors," (ML081830003, NOC-AE-08001783)

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STP Nuclear Operating Company (STPNOC) submits this supplemental response to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors." STPNOC previously closed most of the sump debris blockage issues identified in GL 2004-02 for STP Units 1 and 2. Final closure was pending completion of testing and finalization of the design basis as described in Reference 2 and Reference 5. The enclosed response was prepared using the content guidance of Reference 1 with intent of allowing the NRC to make final closure of this issue for STP Units 1 and 2. As stated in Reference 2 and Reference 5 and approved in Reference 3 and Reference 6, STPNOC is submitting by this letter, verification of completion of all GL 2004-02 corrective actions and confirming compliance with the regulatory requirements listed in GL 2004-02.

STPNOC has implemented hardware modifications to install new emergency sump strainers. The strainers have been qualified by prototypical testing using the design basis debris loading. The analyses that support the design modifications include numerous conservatisms to provide margin to account for the uncertainties that exist in the various aspects of this issue.

STPNOC notes that the NRC Staff has reviewed Westinghouse Topical Report WCAP-16793 Revision 0 concerning evaluation of long term cooling but has not issued a final Safety Evaluation on this report. The STP analysis is in accordance with WCAP-16793. When the final Safety Evaluation for WCAP-16793 is issued, it will be reviewed for impact; and the evaluation of long term cooling will be revised as appropriate.

The enclosure from Reference 4 has been revised to include new information for the STP sump strainer testing and various evaluations. The revised enclosure is attached. Changes from Reference 4 are indicated in the margin of the enclosure.

Commitments included in this letter are provided in Attachment 1.

If you have any questions concerning the content of this supplemental response, please contact Mr. Jamie L. Paul at (361) 972-7344, or me at (361) 972-7867.

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

Executed on 11 December, 2008.

David W. Rencurrel
Site Vice President

JLP/

Attachment 1: List of Commitments
Enclosure: Supplement 4 to the Response to Generic Letter 2004-02

cc:
(paper copy)

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Commitments

The following table identifies the actions in this document to which the STP Nuclear Operating Company has committed. Statements in this submittal with the exception of those in the table below are provided for information purposes and are not considered commitments. Please direct questions regarding these commitments to Jamie L. Paul at (361) 972-7344.

Commitment	Expected Completion Date	CR Action No.
When the final Safety Evaluation for WCAP-16793, "Long Term Cooling" is issued, STP will review it for impact; and the evaluation of long term cooling will be revised as appropriate.	30 June, 2009	02-5326-120

Enclosure

Supplement 4 to the Response to Generic Letter 2004-02

1. Overall Compliance

Upon review of the requirements listed in Generic Letter (GL) 2004-02, STP Nuclear Operating Company (STPNOC) performed an evaluation of the Emergency Core Cooling System (ECCS) and Containment Spray System (CSS) recirculation functions. The evaluation demonstrated that modifications were needed to establish the new design basis. STPNOC has implemented these modifications to meet the required schedule as discussed below.

Plant hardware modifications developed in response to issues identified in GL2004-02 are installed in STP Units 1 and 2 and are supporting compliance with the current design and licensing basis regulatory requirements for long term cooling following a design basis loss of coolant accident. Similarly implementation is complete for STPNOC plant administrative procedures and processes needed to support the GL2004-02 hardware modifications and revised operating practices, as well as to support the assumptions, initial conditions and conclusions of GL2004-02 related evaluations, including evaluations of design basis accident debris generation and transport, sump strainer performance, impact of chemical effects and downstream effects of debris. Since hardware, operating procedures and administrative controls required to support actions taken in response to issues identified in GL2004-02 are already implemented at STP, STPNOC has high confidence that if an accident of the type described in GL2004-02 were to occur at STP, plant systems and plant operators would respond in a manner consistent with the intent of the GL2004-02 corrective actions, including conformance with the regulatory requirements listed in GL2004-02.

While STPNOC's confidence in expected operator and plant response to an accident is high, the plant design and licensing basis can not be changed until all regulatory requirements affecting associated change processes are complete. Consequently, STPNOC requested an extension to December 12, 2008 to allow full completion of 10CFR50, Appendix B activities to support completion of chemical effects head loss testing, preparation of the associated test report and changing the plant design and licensing bases to be in compliance with actions taken in response to issues identified in GL2004-02 (Reference 5 to the cover letter). The NRC approved the request in Reference 6 to the cover letter.

2. General Description of and Schedule for Corrective Actions

STPNOC has implemented sump design modifications to meet the required schedule as discussed below. The design basis and licensing basis for the plant has been updated to reflect the corresponding changes due to the new regulatory requirements.

For the sump performance evaluation, STPNOC joined with other plants in the Strategic Teaming and Resource Sharing (STARS)/ Utilities Service Alliance (USA) group to engage a contractor team headed by Westinghouse Electric Co. along with Alion Science and Technology and Enercon Services, Inc. Sump evaluation activities include the following:

- Containment walkdowns
- Debris generation and transport analysis
- Calculation of required and available net positive suction head (NPSH)
- Screen requirements
- Screen structural analyses
    - Potential or planned design/operational/procedural modifications
    - Downstream effects evaluation
    - Upstream effects evaluation
    - Chemical effects evaluation

STPNOC also joined with other plants in the STARS/USA group to contract with Performance Contracting Inc. (PCI) to provide an advanced design sump strainer for each respective plant. The new sump strainer has replaced the original sump screens for STP. Laboratory testing has been performed by PCI (Alden Research Laboratory and Areva NP are the sub-contractors for this testing) to demonstrate acceptability of the new sump strainer design.

STPNOC is in full compliance with the regulatory requirements discussed in the applicable regulatory requirements section of GL2004-02.

A three-dimensional computational fluid dynamics (CFD) analysis for debris transport was performed to define the debris loading on the sump strainers and also determine the need to install any debris interceptors. It was determined that debris interceptors were not required.

A revision to the sump water level calculation was prepared to support the CFD analysis and to address the items identified in the upstream effects evaluation that was prepared by Enercon.

A latent debris walkdown inside containment was performed to validate the conservative assumptions used for latent debris in the debris generation analysis.

The design for the new sump strainers was validated by testing. The test goals were to demonstrate that the thin-bed effect is not a concern and that the head loss due to the STP plant-specific debris loading is acceptable. The testing scheduled for July 2008 is complete and will be discussed later in this response.

Coatings testing was conducted by Westinghouse to demonstrate that the zone of influence (ZOI) for coatings may be defined using a radius of 5D (5 times the diameter of the break pipe). This result is used to reduce the debris loading on the sump and to demonstrate margin for the new sump strainer design.

The following plant modifications were implemented in Unit 1 during the Fall 2006 refueling outage and in Unit 2 during the Spring 2007 refueling outage:

- Remove existing sump screens from each of the three emergency sumps.
- The vortex breakers will remain in place.
- Install new emergency sump strainer modules by bolting the support frame to the floor. Modules are bolted to the frame.

3. Specific Information Regarding Methodology for Demonstrating Compliance

Content Guide Item 3.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.*

Content Guide Item 3.a - Break Selection

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

Response

In the debris generation calculation various breaks were evaluated in the Reactor Coolant System (RCS) and connected piping.

Break selection consists of determining the size and location of the high energy line breaks (HELB) that produce debris and potentially challenge the performance of the sump screen. The break selection process evaluated a number of break locations to identify the location that is likely to present the greatest challenge to post-accident sump performance. The debris inventory and the transport path were considered when making this determination.

Regulatory guidance recommends that a sufficient number of breaks bounding variations in debris size, quantity, and type be identified. STP evaluated a number of break locations and piping systems, and considered breaks that rely on recirculation to mitigate the event. The following break locations were considered.

Break Criteria 1 - Breaks in the RCS with the largest potential for debris
Break Criteria 2 - Large breaks with two or more different types of debris
Break Criteria 3 - Breaks in the most direct path to the sump
Break Criteria 4 - Medium and large breaks with the largest potential particulate debris to fibrous insulation ratio by weight

Break Criteria 5 - Breaks that generate an amount of fibrous debris that, after transport to the sump screen, could form a uniform thin bed (i.e., usually 1/8" thick) that could subsequently filter sufficient particulate debris to create a relatively high head loss referred to as the "thin-bed effect".

This spectrum of breaks is consistent with that recommended in the NRC's Safety Evaluation Report (SER) for the Nuclear Energy Institute (NEI) Guidance Report (GR), NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology." It is also consistent with regulatory position 1.3.2.3 of Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," Revision 3.

Locations were selected for the breaks that produce the maximum amount of debris and also the worst combination of debris mixes with the possibility of being transported to the sump screen. Section 3.3.5.2 of the SER advocates break selection at 5-ft intervals along a pipe in question but clarifies that "the concept of equal increments is only a reminder to be systematic and thorough". It further qualifies that recommendation by noting that a more discrete approach driven by the comparison of debris source term and transport potential can be effective at placing postulated breaks. The key difference between many breaks (especially large breaks) is not the exact location along the pipe, but rather the envelope of containment material targets that is affected.

A small break loss of coolant accident (SBLOCA) inside the secondary shield wall was evaluated for STP. The debris generated by the SBLOCA is less than the debris generated by the large break loss of coolant accident (LBLOCA); however the containment water level at the time of recirculation would be less than the water level caused by the LBLOCA which results in higher average fluid velocities and increases the transportation of debris to the containment sump

For SBLOCAs outside the secondary shield wall, SER Section 3.3.5.2 stipulates the need to evaluate breaks in RCS-attached piping beyond isolation points is contingent upon the determination that recirculation would not be required should a break occur in these sections. The debris generation analysis for STP considered the failure of a single isolation valve inside the secondary shield wall and includes SBLOCAs outside the secondary shield wall in the spectrum of events evaluated to ensure these would not be limiting

Breaks in the RCS with the largest potential for debris (Break Criterion 1)

The break with the largest potential for debris generation is the largest break in an area with the largest concentration of debris source material. For STP, there were seven possible break locations that have the potential to generate the largest concentration of debris:

1. 29" hot leg (LBLOCA) located inside the steam generator compartment inside the secondary shield wall.
2. A hot leg line break in the other compartment was also evaluated since the layout of the STP containment is such that the steam generator compartments each contain two RCS loops.
3. 31" ID RCS cross-over line (LBLOCA), located inside the steam generator compartment inside the secondary shield wall.
4. RCS Nozzle (LBLOCA) in the reactor vessel cavity.
5. 12" residual heat removal (RHR) pump suction line from the RCS hot leg (SBLOCA), located outside the secondary shield wall, but inside the RHR pump/heat exchanger compartment.
6. 8" SI pump discharge line to the RCS hot leg (SBLOCA), located outside the secondary shield wall.
7. 4" chemical and volume control system (CVCS) letdown line (SBLOCA) from the RCS Loop 3 cross-over pipe inside the steam generator (SG) compartment. This break was analyzed because it is the largest pipe break postulated that allows the control room operators time to isolate the safety injection (SI) accumulators before they discharge into the RCS.

Large breaks with two or more different types of debris (Break Criterion 2).

The debris generated by the RCS hot leg line break and the reactor vessel cavity nozzle break discussed in Break Criterion 1 bound the break under criterion 2. The types of insulation debris within the primary shield wall are reflective metal insulation (RMI) and Marinite, and the types of insulation within the secondary shield wall are NUKON™, Thermal-Wrap and Microtherm®.

Breaks with the most direct path to the sump (Break Criterion 3).

The 12" RHR pump suction lines (A, B and C) from the RCS hot legs have second isolation valves that are located outside the secondary shield wall presenting a potential for direct transport to the sump. Though these isolation valves are inside the RHR pump/heat exchanger rooms, which are separated from the area where the containment sumps are located and therefore to do not provide a direct path to the sumps, a break in this line was included in the STP analyses. The "A" and "B" SI system discharge lines to the RCS hot legs also have isolation valves outside the secondary shield wall but are located on the opposite side of containment away from the sump. A break in these lines was also included in the analysis.

Large breaks with the largest potential particulate debris to fibrous insulation ratio by weight (Break Criterion 4).

The types of insulation identified within the containment are RMI, NUKON™, Thermal-Wrap, Microtherm® and Marinite. Since STP has a very limited quantity of particulate type insulation with respect to the fibrous insulation, and this particulate insulation is affected by the LBLOCAs evaluated in accordance with Break Criterion 1, large breaks with the largest potential particulate debris to fibrous insulation ratio is bounded by Break Criterion 1.

Breaks that generate a "thin bed" – high particulate with 1/8" fiber bed (Break Criterion 5)

Break Criterion 5 postulates a scenario that could generate an amount of fibrous debris that, after its transport to the sump screen, could form a uniform thin bed that could subsequently filter sufficient particulate debris to create a relatively high head loss referred to as "the thin-bed effect" (TBE). The quantity of fiber needed to form a thin bed is the quantity of fiber that would form a 1/8" thick uniform debris bed on the entire surface area of the sump screen.

The STP Debris Accumulation and Head Loss Analysis does consider a thin fibrous bed on the sump screens. The STP containment contains a large quantity of fibrous insulation, which is postulated to become transportable debris due to a LBLOCA. Therefore, the analysis does consider a thin fibrous debris bed as well as the maximum fibrous debris bed.

Content Guide Item 3.a - Break Selection

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

Response

The large main steam and feedwater line breaks were not evaluated since recirculation is not required under the plant licensing basis for STP.

Content Guide Item 3.a - Break Selection

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

Response

A postulated LBLOCA of the Loop "C" hot leg at the steam generator generates the maximum possible quantity of fibrous debris at STP. This break also produces some Microtherm® insulation debris. These LBLOCA debris quantities are significant due to the large zones of influence (ZOI). One other LBLOCA case analyzed is in the RCS hot leg at the reactor vessel nozzle. This break produced Marinite insulation debris and significantly less fibrous insulation debris. This break also produces RMI insulation debris and Microtherm® insulation debris. The make up of the total debris generated by these two breaks were different enough to warrant separate transport and head loss analysis to ensure that the head loss at the Containment Sump is thoroughly evaluated.

Content Guide Item 3.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/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.*

Response

As noted in section 3.4.2.2 of the SER, the debris generation analysis considers the ZOI to be defined based on the material with the lowest destruction pressure. Refinements in the STP analysis include debris-specific (insulation material specific) and non-spherical ZOIs. The debris-specific refinements, as endorsed in SER Section 4.2.2.1.1, provide relief as long as there are two or more distinct types of insulation within the break location. In the STP containment, there are two or more distinct types of insulation and a debris-specific refinement is beneficial in this analysis. The destruction pressures and associated ZOI radii for the insulating materials in the STP containment are listed in .

Table 1 – Destruction Pressures and ZOI Radii for Potential Debris Sources

Insulation Types	Destruction Pressure (psi)	ZOI Radius (Radius/Break Diameter)	Reference/Basis
Transco RMI	114	2.0	SER Table 3.2
NUKON™	18.6	7	Westinghouse Test Report WCAP 16710
Thermal-Wrap	18.6	7	Assumed the same as NUKON™ based on GR 3.4.3.3.1
Marinite	114	2.0	See discussion below
Microtherm®(1)	2.4	28.6	See discussion below

Marinite

The SER does not recommend a destruction pressure or ZOI for this material and insufficient data exists on its material properties and destruction pressure. However, since this insulation is covered with 3/16" stainless steel plate, the destruction pressure was assumed to be equivalent to that of RMI. This destruction pressure is 114 psig, which corresponds to a ZOI of 2.0D.

Microtherm®

The material specifications for Microtherm were insufficient to determine an appropriate destruction pressure and ZOI. Therefore, the lowest destruction pressure (Min-K at 2.4 psi) and the greatest ZOI (also Min-K at L/D of 28.6) identified in Table 3-2 of the SER were utilized in the STP analysis.

Robust barriers, i.e., structures and equipment that are impervious to jet impingement, are assumed to prevent further expansion of the break jet. The volume of a spherical ZOI with a radial dimension extending beyond robust barriers such as walls or encompassing a large component such as a tank or steam generator is truncated by the barrier. The SER stipulates that deflection/reflection need not be considered but "shadow" surfaces of components should be included in the analysis.

ZOIs were not applied within the primary shield wall due to the relatively small area between the reactor vessel and the primary shield wall. All of the insulation material within the primary shield wall was considered to be destroyed by a LBLOCA within the primary shield wall.

The debris generation analysis identified a LBLOCA break in the Loop C 29" hot leg Line break at the steam generator and the RCS hot leg line break at a nozzle in the reactor cavity as the two limiting breaks in the RCS. The debris quantities for these two breaks as well as Loop A hot leg and the 4" CVCS letdown line are presented in .

Table 2 – Summary of Debris Generation for Breaks in the RCS

Insulation Type	Loop "A" hot leg Line Break	Loop "C" hot leg Line Break	RCS hot leg Nozzle Line Break	4" CVCS Letdown Pipe Break (SBLOCA)
Marinite	0	0	15.2 ft^3	0
RMI	0	0	24,493 ft^2	0
NUKON™	297.2 ft^3	317.8 ft^3	33.0 ft^3	2.6 ft^3
Thermal-Wrap	239.8 ft^3	239.8 ft^3	0 ft^3	0 ft^3
Microtherm®	4.3 ft^3	3.2 ft^3	0.9 ft^3	0

The breaks associated with the potential for direct transport to the sump (Break Criterion 3) resulted in a limiting NUKON™ debris generation of 17.9 ft^3 for the 12" RHR suction lines and 2.5 ft^3 for the 8" SI pump discharge lines.

Miscellaneous Solid Debris

The STP debris generation analysis does recognize the presence of miscellaneous solid object debris sources, such as equipment labels and tags, and plastic signs. As suggested by the GR, this miscellaneous solid object debris source is bounded by 100 ft^2 , and includes an allowance of 14 ft^2 for 100 equipment clearance order (ECO) tags (size of 4" x 5") and 2 ft^2 for ty-wraps.

Content Guide Item 3c. Debris Characteristics

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

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

The debris sources for STP include insulation, coatings, and latent debris. The insulation debris types include RMI, NUKON™, Thermal-Wrap, Microtherm® and Marinite. The RMI is located on the reactor vessel inside the primary shield wall. The NUKON™ is located on various piping and equipment throughout containment. The Thermal-Wrap is installed on the steam generators. Marinite is installed on the reactor vessel nozzles. The Microtherm® is used on some piping in the secondary shield wall penetrations. The characteristics of the insulation debris materials are discussed in this section as the characteristics of the other debris types (e.g., coatings and latent) are included elsewhere.

Content Guide Item 3c. Debris Characteristics

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

Response

An additional refinement to this Debris Generation Analysis is the use of a 3-size distribution for the Low Density Fiberglass (LDFG). Westinghouse proprietary analysis of data from both the BWROG (Boiling Water Reactor Owners' Group) air jet impact testing (AJIT) and the drywell debris transport study (DDTS) described in NUREG/CR-6369 provides basis for NUKON^{tm} debris size distribution and ZOI. Westinghouse LTR-SEE-I-08-148 provides basis for the applicability of this analysis to South Texas Project. The 3-size distribution is a result of 2 separate ZOIs (5D and 7D) centered on the pipe break location. The 3 different sizes of destroyed debris are categorized as: Small Fines, Large Pieces and Intact Blankets. The results of this analysis support use of the following size distributions for NUKON^{tm} and/or Thermal-Wrap insulation at STP in the CFD analysis.

Table 3 – LDFG Debris Distribution Within Each Sub-Zone

SIZE	(5.0 L/D)	(7.0 – 5.0 L/D)
Small Fines	60%	0%
Large Pieces (>4" on a side)	40%	0%
Intact (covered) Blankets	0%	100%

Table 4 summarizes the other potential debris sources in the STP containment and the associated debris size distributions from Table 3-3 of the SER. Materials for which debris generation is not known well enough to conservatively estimate debris size distribution will assume maximum destruction as 100% fines.

Table 4 – Debris Size Distribution

Material	Percentage Small Fines	Percentage Large Pieces
Within the ZOI		
RMI	75	25
Marinite	100	0
Microtherm®	100	0
Outside the ZOI		
Covered Undamaged Insulation	0	0

Content Guide Item 3c. Debris Characteristics

- *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.*

Response

Table 5 and Table 6 provide a summary of the as-fabricated densities, microscopic densities, and dimensions for applicable debris types at STP. Characteristics associated with coatings will be further discussed later in this report.

Table 5 – Fibrous Material Characteristics

Debris Material	As-Fabricated Density (lb/ft^3)	Microscopic Density (lb/ft^3)	Characteristic Diameter (μm)
NUKON™	2.4	175	7 μm
Thermal-Wrap	2.4	159	5.5 μm

Table 6 – Particulate Debris Characteristics

Debris Material	As-Fabricated Density (lb/ft^3)	Microscopic Density (lb/ft^3)	Characteristic Diameter (μm)
Marinite (1)	14.5	144	5
Microtherm®	15	187	2.5 to 20

The material characteristics for Marinite are assumed to be the same as those identified for Calcium Silicate due to their similar appearances.

Content Guide Item 3c. Debris Characteristics

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

Response

The specific surface area (Sv) was only used for preliminary analytically determined head loss values across a debris laden sump screen using the correlation given in NUREG/CR-6224. Since the head loss across the installed sump screen is determined via testing, these values are not used in the design basis for STP. Therefore, these values are not provided as part of this report.

Content Guide Item 3c. Debris Characteristics

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

Response

There are no such assumptions that differ from the guidance.

Content Guide Item 3d. Latent Debris

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

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

Response

The latent debris at STP has been evaluated through containment condition assessments. Containment walkdowns were completed for Unit 1 and for Unit 2. The conditions were completed in accordance with the guidance of NEI 02-01, "Condition Assessment Guidelines, Debris Sources Inside Containment," Revision 1. The quantity and composition of the latent debris was evaluated by extensive sampling for latent debris (dirt/dust and latent fiber) considering the guidance in NEI 04-07, Volume 2.

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

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

Samples were taken for Unit 1. The visual assessments and walkdowns supported that there were no significant differences between the Units that would affect the quantity or types of latent debris. Therefore, the samples taken are representative of both Units.

The results of the latent debris calculation conservatively determined the debris loading to be less than 160 lbm in each containment. Therefore, it was elected to use a conservative bounding value of 200 lbm for the latent debris source term in containment.

Visual examination of the debris showed very low fiber content. In lieu of analysis of samples, conservative values for debris composition properties were assumed as recommended by NEI 04-07 Volume 2. This results in a very conservative estimate of fiber content. The particulate / fiber mix of the latent debris will be assumed to be 15% fiber. The latent debris source term value incorporated into the STP analysis is presented in Table 7.

Table 7 – Latent Debris Source Term

Latent Debris Type	Mass (lbm)	Density (lbm/ft^3)	Characteristic Size (ft)
Dirt and Dust	170	169	5.67E-05
Latent Fiber	30	175	2.3 E-05

The containment condition assessments also included the identification of miscellaneous solid objects such as labels and tags. Qualified tags attached with stainless steel wires were found for much of the equipment. Unqualified items were identified and removed. The total surface area for any remaining debris of this type was determined to be much less than 100 ft^2. Therefore, as suggested by NEI 04-07, this miscellaneous solid object debris source is bounded by the 100 ft^2 that was implemented in the STP debris generation and transport analyses.

STP has identified tags and labels which are qualified and which have been shown to not transport to the emergency sump strainers (acceptable labels).

Content Guide Item 3e. Debris Transport

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

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

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

Content Guide Item 3e. Debris Transport

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

Response

The methodology used in the transport analysis is based on 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. The specific effect of each of the four modes of transport was analyzed for each type of debris generated. These modes of transport are:

- *Blowdown transport* – the vertical and horizontal transport of debris to all areas of containment by the break jet.
- *Washdown transport* – the vertical (downward) transport of debris by the containment sprays and break flow.
- *Pool fill-up transport* – the transport of debris by break and containment spray flows from the refueling water storage tank (RWST) to regions that may be active or inactive during recirculation.
- *Recirculation transport* – the horizontal transport of debris from the active portions of the recirculation pool to the sump screens by the flow through the emergency core coolant system (ECCS).

The logic tree approach was then applied for each type of debris determined from the debris generation calculation. The logic tree shown in is somewhat different than the baseline logic tree provided in the GR. This departure was made to account for certain non-conservative assumptions identified by the SER including the transport of large pieces, erosion of small and large pieces, the potential for washdown debris to enter the pool after inactive areas have been filled, and the direct transport of debris to the sump screens during pool fill-up. Also, the generic logic tree was expanded to account for a more refined debris size distribution. (Note that some branches of the logic tree may not be required for certain debris types).

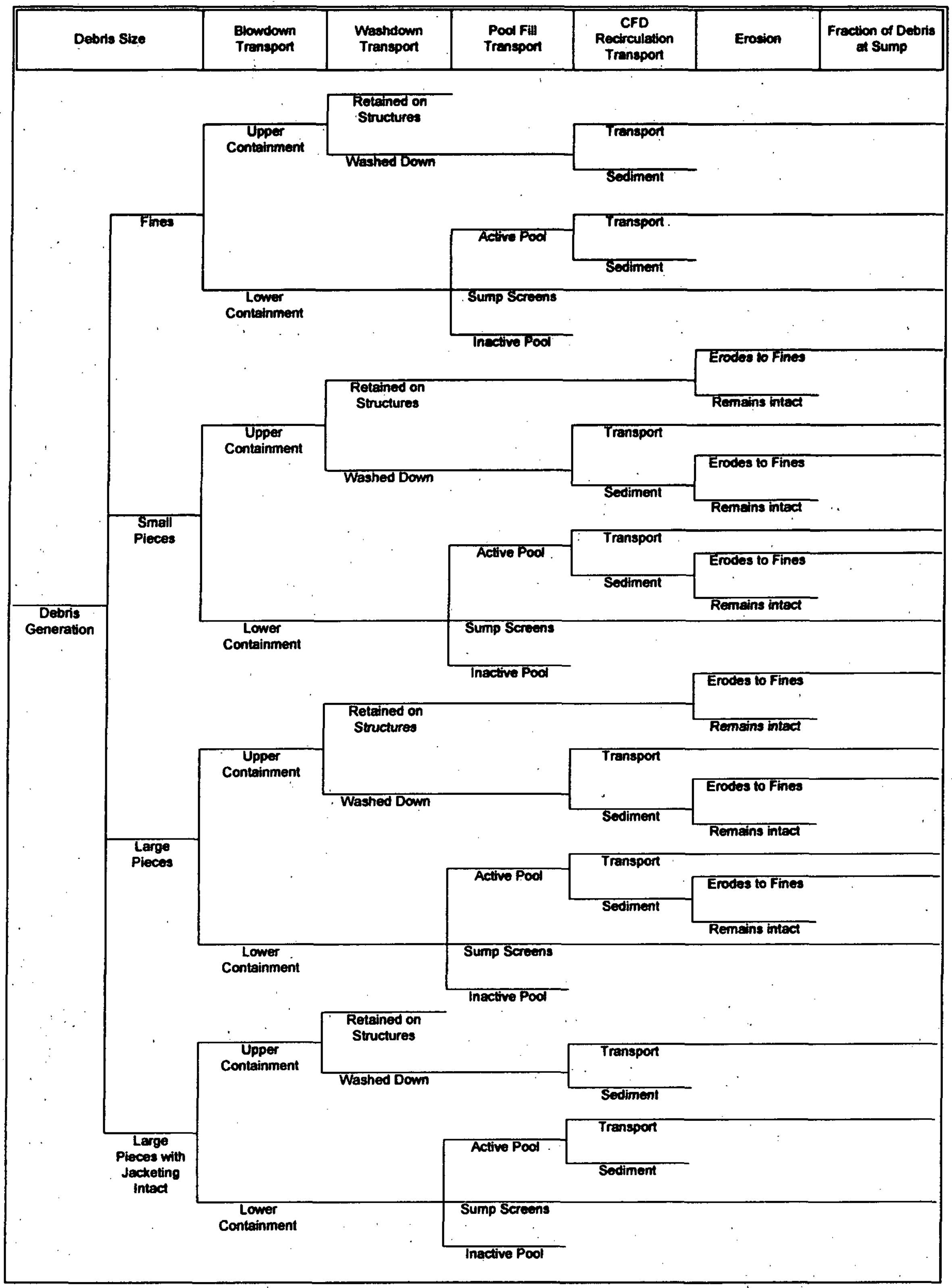


Figure 1 – Generic debris transport logic tree

The basic methodology used for the South Texas Project transport analysis is shown below:

1. Based on many of the containment building drawings, a three-dimensional model was built using computer aided design and drafting (CADD) software.
2. A review was made of the drawings and CADD model to determine transport flow paths. Potential upstream blockage points including screens, fences, grating, drains, etc. that could lead to water holdup were addressed.
3. Debris types and size distributions were gathered from the debris generation calculation for each postulated break location.
4. The fraction of debris blown into upper containment was determined based on the relative volumes of upper and lower containment.
5. The quantity of debris washed down by spray flow was conservatively determined.
6. The quantity of debris transported to inactive areas or directly to the sump screens was calculated based on the volume of the inactive and sump cavities proportional to the water volume at the time these cavities are filled.
7. Using conservative assumptions, the locations of each type/size of debris at the beginning of recirculation was determined.
8. A computerized flow dynamics (CFD) model was developed to simulate the flow patterns that would occur during recirculation.
9. A graphical determination of the transport fraction of each type of debris was made using the velocity and turbulent kinetic energy (TKE) profiles from the CFD model output, along with the determined initial distribution of debris.
10. The recirculation transport fractions from the CFD analysis were gathered to input into the logic trees.
11. The effects of erosion on the LOCA generated debris were evaluated to determine the potential significance.
12. The overall transport fraction for each type of debris was determined by combining each of the previous steps in logic trees.

BLOWDOWN TRANSPORT

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

The volumes for the upper containment (including the refueling canal and areas above the operating deck) and for lower containment (including the open area inside the steam generator and pump enclosures, the area inside the secondary shield wall, and the annulus area below the operating deck) were determined from the CADD model. Because the debris was assumed to be carried with the blowdown flow, the flow split is then proportional to the containment volumes. This resulted in a transport fraction for the fine debris to upper containment of 69%.

The drywell debris transport study (DDTS)[1] testing provides debris holdup values for blowdown occurring in a wetted and highly congested area. Values associated with grating being present in the blowdown flowpath were utilized in the STP blowdown analysis. The DDTS also presents values for

[1] D.V. Rao, et al., "Drywell Debris Transport Study: Experimental Work", NUREG/CR-6369, Volume 2, September 1999.

holdup when blowdown travels a flow path with 90° turn(s). Although 90° turns might not have to be negotiated by debris blown to upper containment at STP, significant bends would have to be made. Therefore, it was estimated that 5% (versus the 17% value in the study) of the small fiberglass debris blown upward would be trapped due to changes in flow direction.

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

Table 8 and Table 9 show the transport fractions for each type/size of debris to upper containment and to the containment pool due to the blowdown forces for breaks inside the steam generator compartments. Table 10 through Table 13 show the blowdown transport fractions for the break inside the reactor cavity and the small breaks outside the secondary shield wall. Note that debris outside the ZOI is not affected by the blowdown, and therefore the transport fraction for this debris would be 0%.

Table 8 – Blowdown transport fraction of debris to upper containment (Cases 1 and 5)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
LDFG	69%	NA	0%	0%
Microtherm™ (Case 1)	69%	NA	NA	NA
Qualified Coatings (inside ZOI)	69%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

Table 9 – Blowdown transport fractions of debris to containment pool (Cases 1 and 5)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
LDFG	31%	NA	0%	0%
Microtherm™ (Case 1)	31%	NA	NA	NA
Qualified Coatings (inside ZOI)	31%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

Table 10– Blowdown transport fractions of debris to upper containment (Case 2)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	0%	0%	NA
LDFG	69%	NA	0%	0%
Marinite™	0%	NA	NA	NA
Qualified Coatings (inside ZOI)	0%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

Table 11 – Blowdown transport fractions of debris to containment pool (Case 2)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI	NA	100%	100%	NA
LDFG	31%	NA	0%	0%
Marinite™	100%	NA	NA	NA
Qualified Coatings (inside ZOI)	100%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	100%	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

Table 12 – Blowdown transport fractions of debris to upper containment (Cases 3 and 4)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
LDFG	0%	NA	0%	0%
Qualified Coatings (inside ZOI)	0%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

Table 13 – Blowdown transport fractions of debris to containment pool (Cases 3 and 4)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
LDFG	100%	NA	100%	100%
Qualified Coatings (inside ZOI)	100%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

WASHDOWN TRANSPORT

During the washdown phase, debris in upper containment could be washed down by the containment sprays. For STP, some small piece debris as well as all large pieces would be held up by grating.

The debris blown to upper containment was assumed to be scattered around and a reasonable approximation of the washdown locations was made based on the spray flow split in upper containment. This resulted in the following washdown split: 26% of the containment sprays were estimated to flow directly into the steam generator compartments, 31% were estimated to flow into the steam generator compartments via the refueling canal (28.5%) and cable tray chase (2.7%), and the remaining 43% of the sprays were estimated to flow into the annulus.

Multiple levels of grating are present in the STP Containment. The results of the DDTS testing showed that approximately 40-50% of small fiberglass debris landing on grating would be washed through the grating due to spray flows. (Note that the spray flow at the plant is on the lower end of the 1 to 12 gpm/ft2 spray flow used in the testing). Holdup of small pieces of fiberglass debris was credited at each level of grating that washdown flow passed through. Credit was also taken for holdup of small pieces of RMI on grating based on the BWR URG, which indicates that the retention of small RMI debris on grating is approximately 29%.

The following tables show the fraction of debris in upper containment and the steam generator compartments that would be expected to transport to the pool floor inside and outside the secondary shield wall.

Table 14 – Washdown transport fractions of debris from upper containment to the annulus

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
LDFG	43%	3%	0%	0%
Microtherm™ (Case 1)	43%	NA	NA	NA
Qualified Coatings (inside ZOI)	43%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	NA	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	NA	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Table 15 – Washdown transport fractions of debris from upper containment directly to the steam generator compartments

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
LDFG	26%	NA	0%	0%
Microtherm™ (Case 1)	26%	NA	NA	NA
Qualified Coatings (inside ZOI)	26%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	NA	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	NA	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	NA	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Table 16 – Washdown transport fractions of debris from upper containment to the steam generator compartments via the canal drains and cable tray chase

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
LDFG	31%	NA	0%	0%
Microtherm™ (Case 1)	31%	NA	NA	NA
Qualified Coatings (inside ZOI)	31%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	NA	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	NA	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	NA	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Table 17 – Washdown transport fractions of debris in the steam generator compartments at the end of the blowdown phase

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
LDFG	100%	NA	0%	0%
Microtherm™ (Case 1)	100%	NA	NA	NA
Qualified Coatings (inside ZOI)	100%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	NA	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	NA	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	NA	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

POOL FILLUP TRANSPORT

During pool fill-up, the flow of water transports insulation debris from the break location to all areas of the recirculation pool. Some of the debris was assumed to transport to inactive areas of the pool and some was assumed to transport directly to the sump screens as the emergency sump cavities are filled. The cavities considered for pool fill up transport include the containment sump, the elevator pit, and the three ECCS sumps. Other potentially inactive areas where debris could be held up including the secondary normal sump were conservatively assumed to be negligible and were not credited.

Assuming that fine debris is uniformly distributed in the pool, and the water entering the pool from the break and sprays is clean (i.e. washdown of debris in upper containment occurs after inactive cavities have been filled), the transport to each of the inactive cavities was calculated for STP. (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.)

Table 18 – Pool fill-up transport fractions of debris to the two active sumps

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI (Case 2)	NA	0%	0%	NA
LDFG	8%	NA	0%	0%
Marinite™ (Case 2)	8%	NA	NA	NA
Microtherm™ (Case 1)	8%	NA	NA	NA
Qualified Coatings (inside ZOI)	8%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Unqualified epoxy in Reactor Cavity (Case 2 – inside ZOI)	8%	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	8%	NA	NA	NA
Latent Fiber	8%	NA	NA	NA

Table 19 – Pool fill-up transport fractions of debris to the inactive sump

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI (Case 2)	NA	0%	0%	NA
LDFG	4%	0%	0%	0%
Marinite™ (Case 2)	4%	NA	NA	NA
Microtherm™ (Case 1)	4%	NA	NA	NA
Qualified Coatings (inside ZOI)	4%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Unqualified epoxy in Reactor Cavity (Case 2 – inside ZOI)	4%	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	4%	NA	NA	NA
Latent Fiber	4%	NA	NA	NA

Table 20 – Pool fill-up transport fractions of debris to the inactive cavities

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Stainless Steel RMI (Case 2)	NA	0%	0%	NA
LDFG	13%	NA	0%	0%
Marinite™ (Case 2)	13%	NA	NA	NA
Microtherm™ (Case 1)	13%	NA	NA	NA
Qualified Coatings (inside ZOI)	13%	NA	NA	NA
Unqualified Misc Coatings (outside ZOI)	0%	NA	NA	NA
Unqualified epoxy in Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Unqualified epoxy in Reactor Cavity (Case 2 – inside ZOI)	13%	NA	NA	NA
Unqualified epoxy outside Reactor Cavity (outside ZOI)	0%	0%	NA	NA
Dirt/Dust	13%	NA	NA	NA
Latent Fiber	13%	NA	NA	NA

RECIRCULATION TRANSPORT

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

A diagram showing the significant parts of the CFD model is shown below. The sump mass sink, the various direct and wash spray regions, and the combined break and spray wash regions are highlighted.

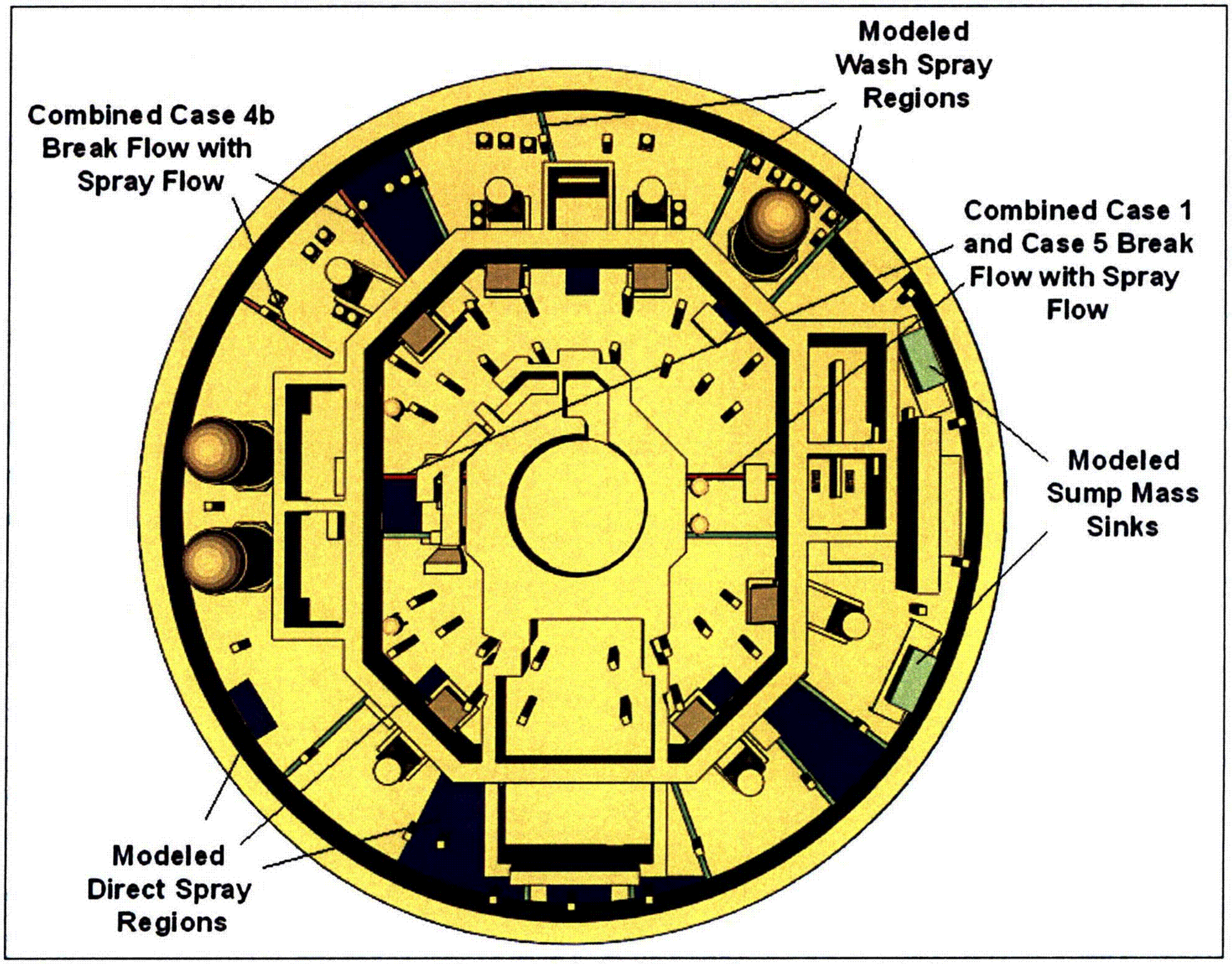


Figure 2 – Diagram of significant features modeled

Flow-3D® Version 9.0 developed by Flow Science Incorporated was used for the CFD modeling. The key CFD modeling attributes/considerations included the following:

Computational Mesh:

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

Modeling of Containment Spray Flows:

From consideration of various plan and section drawings, as well as the containment building CADD model, it was judged that spray water would drain to the pool through numerous pathways. Some of these pathways included: the steam generator compartments through the open area above the steam generators, into the refueling canal and through the refueling canal drains, and into the annulus through the various open sections of grating. The sprays were introduced near the surface of the pool.

Modeling of Break Flow:

STP breaks were modeled at the break location which was not directly above the recirculation pool and consideration of the additional free fall energy was not necessary. The break flow falls onto the floor at the associated elevation and then drains through various paths to the recirculation pool. This break flow was combined with the spray flow and introduced to each region where flow occurs near the surface of the pool.

Modeling of the Emergency Sump:

The emergency sumps at STP consist of three sumps. To bound the transport analysis, the worst case scenario (two sumps operating) was modeled. The two outer sumps were chosen as the active sumps since debris would be more likely to transport to the outer sumps. The mass sink used to pull flow from the CFD model was defined within the two sump cavities. A negative flow rate was set for the sump mass sink, which tells the CFD model to draw the specified amount of water from the pool over the entire exposed surface area of the mass sink obstacle.

Turbulence Modeling:

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

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

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

Steady-State Metrics:

The CFD models were started from a stagnant state at a defined pool depth and run long enough for steady-state conditions to develop. A plot of mean kinetic energy was used to determine when steady-state conditions were reached. Checks were also made of the velocity and turbulent energy patterns in the pool to verify that steady-state conditions were reached.

Debris Transport Metrics:

Metrics for predicting debris transport have been adopted or derived from data. The specific metrics are the turbulent kinetic energy (TKE) necessary to keep debris suspended, and the flow velocity necessary to tumble sunken debris along a floor. The metrics utilized in the STP transport analysis originate from the sources below:

1) NUREG/CR-6772 Tables 3.1, 3.2 & 3.5,
2) NUREG/CR-6808 Table 3.2 and Figure 5-2, or
3) Calculated using Stokes' Law using water properties at 120° F.

Graphical Determination of Debris Transport Fractions

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

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

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

The following figures and discussion are presented as an example of how the transport analysis was performed for a single debris type – Small Piece Stainless Steel RMI. This same approach was utilized for other debris types analyzed at STP.

Figure 4 and Figure 5 show that the turbulence in the pool is only high enough to suspend small RMI debris in the vicinity of the location where break and spray flow from the steam generator compartments enters the pool.

As shown in Figure 3, the small RMI debris was assumed initially to be uniformly distributed inside the secondary shield wall and in the vicinity of the sump screens. This area was overlaid on top of the plot showing tumbling velocity and flow vectors to determine the recirculation transport fraction. The area where small pieces of RMI would transport within the initial distribution area is 1,872 ft^2, as shown in Figure 6. Since the initial distribution area was determined to be 5,977 ft^2 the recirculation transport fraction for small pieces of RMI is 31%.

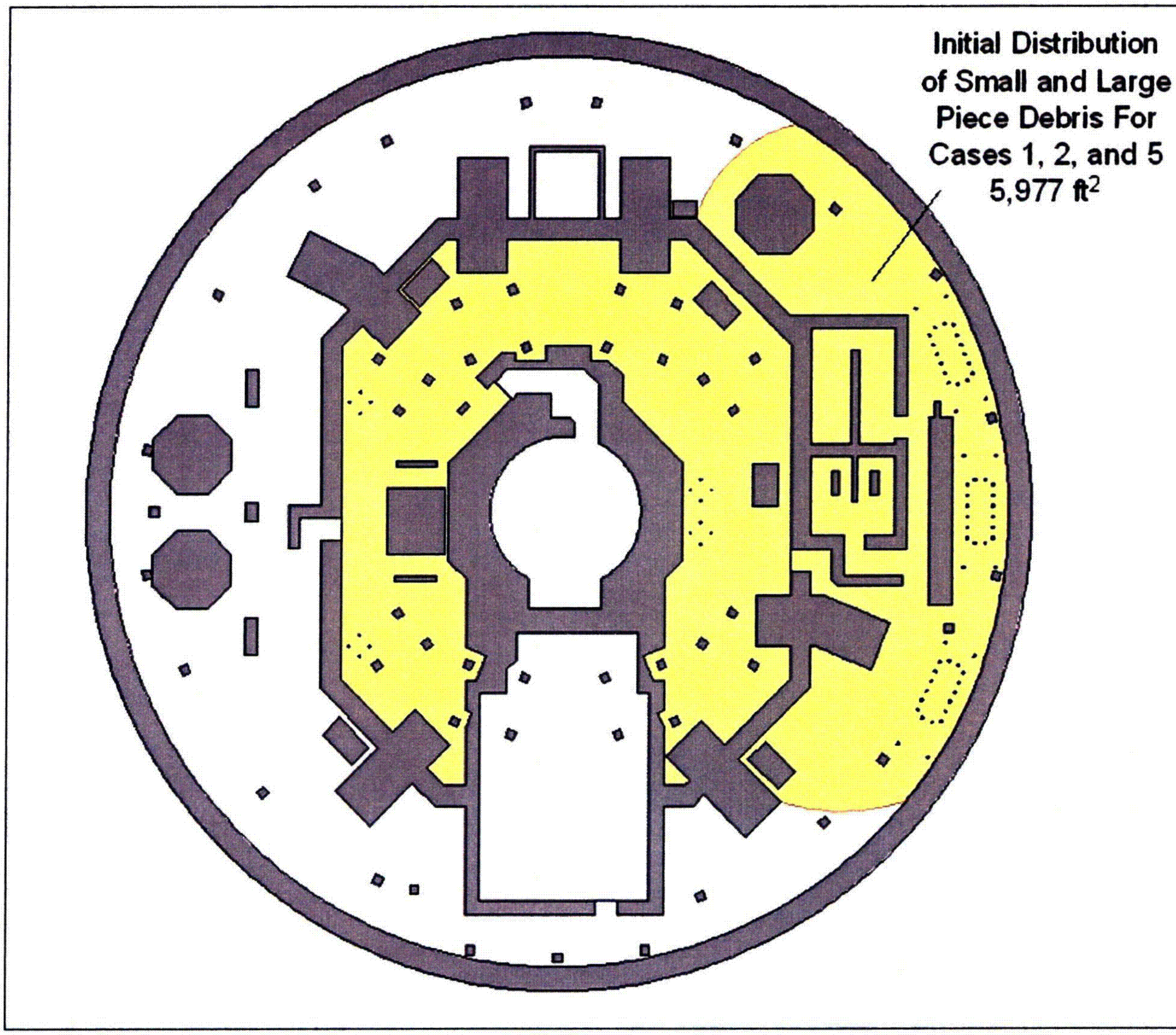


Figure 3 – Distribution of small & large piece debris in lower containment

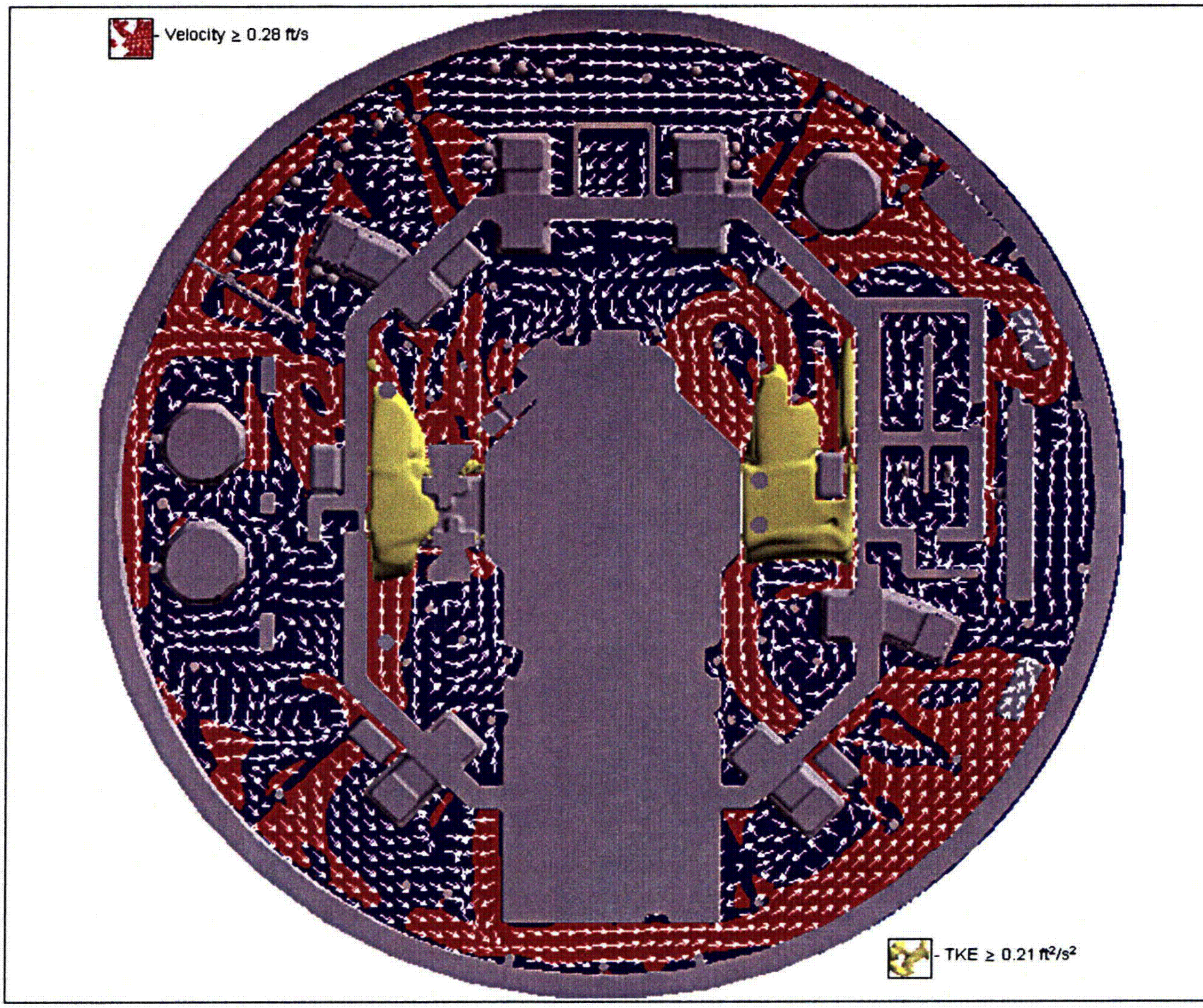


Figure 4 – TKE and velocity with limits set at suspension/tumbling of small pieces of stainless steel RMI

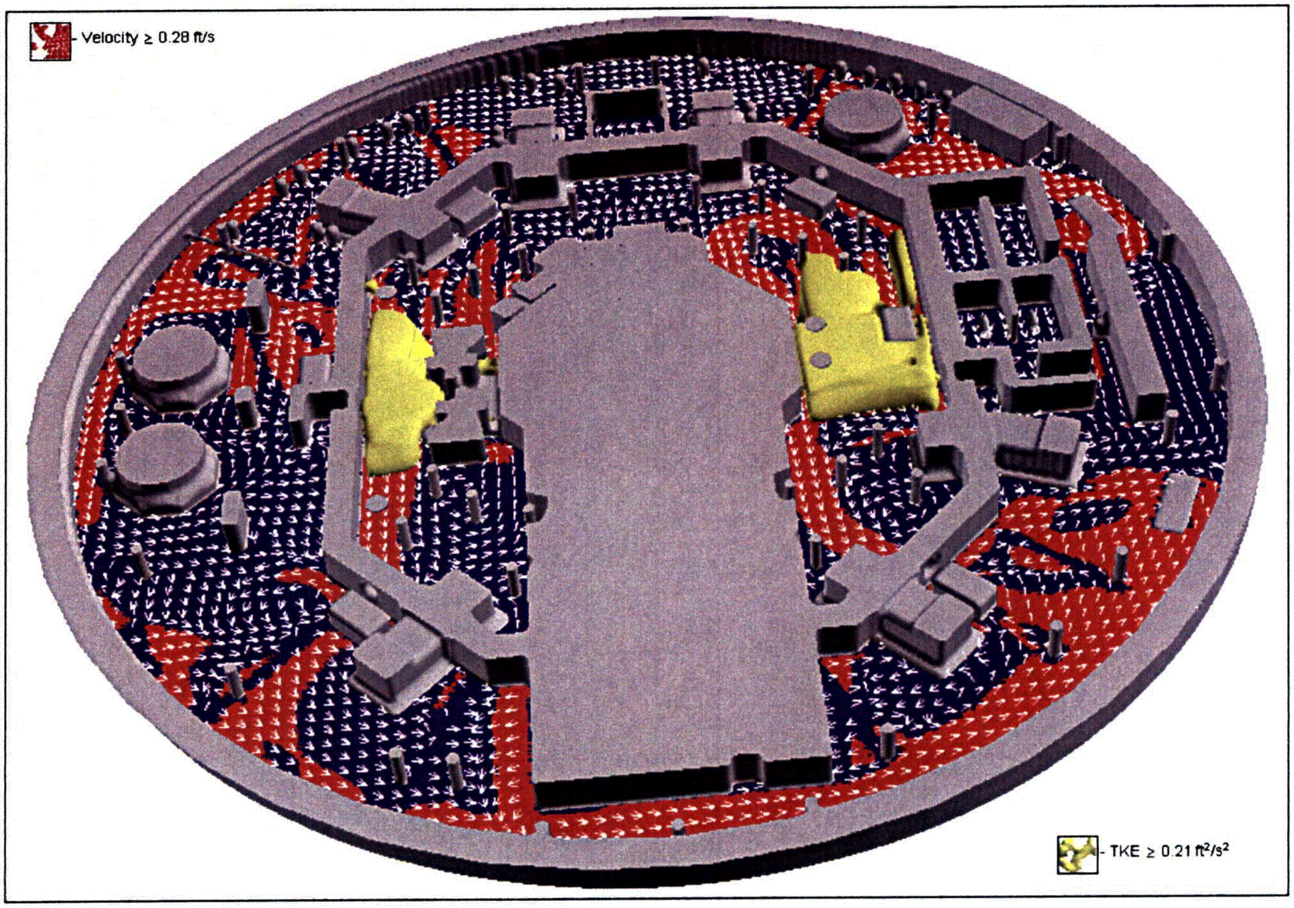


Figure 5 – 3D view of TKE and velocity with limits set at suspension/tumbling of small pieces of stainless steel RMI

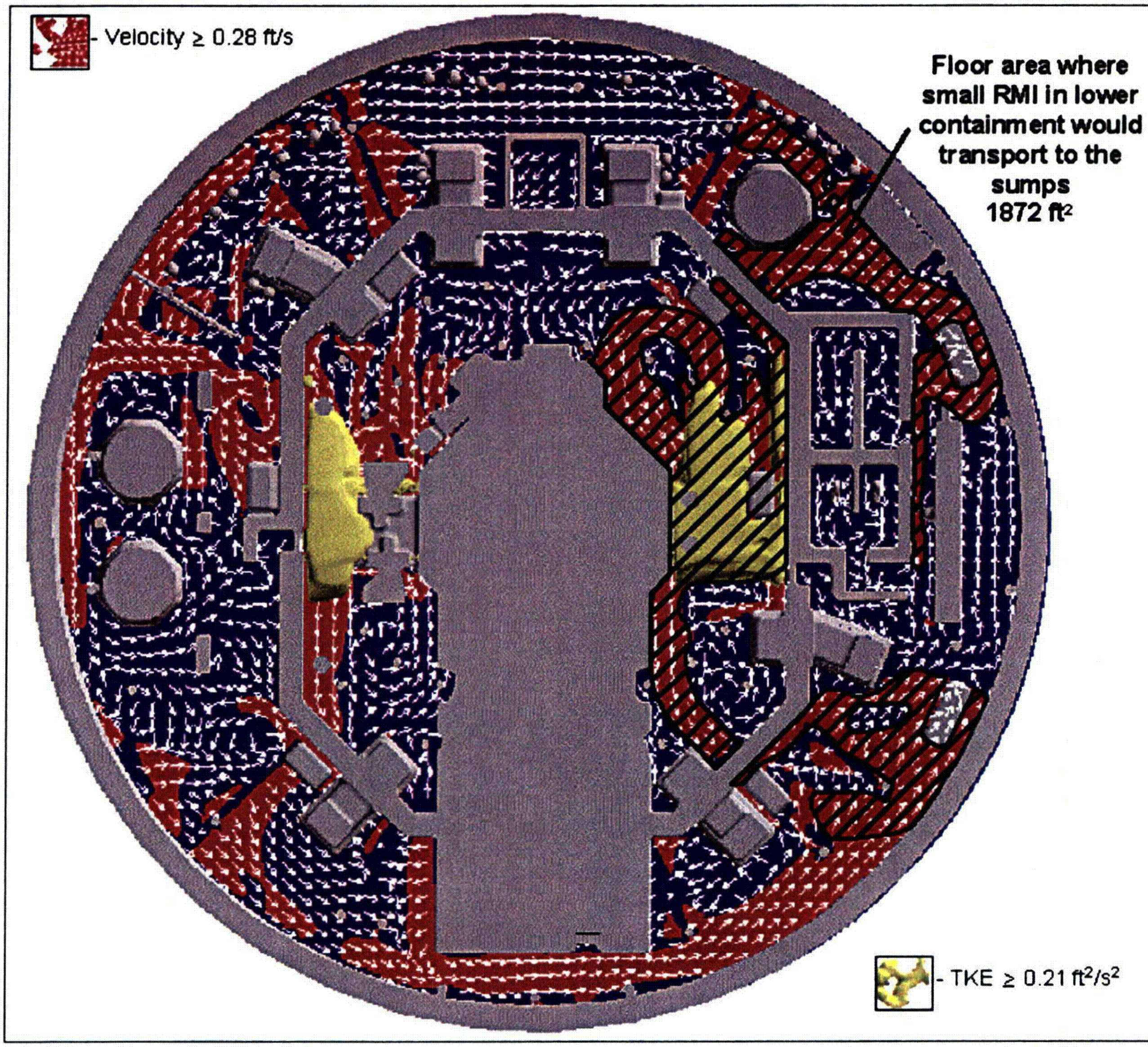


Figure 6 – Floor area where small RMI would transport to the sumps

This same analysis was applied for each debris type (grouping was performed as applicable) evaluated at STP. Recirculation pool transport fractions were identified for each debris type associated with the location of its original distribution. This includes a transport fraction for debris: 1) not originally blown into upper containment, 2) washed down inside the secondary shield wall, and 3) washed down into the annulus.

Content Guide Item 3e. Debris Transport

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

Response

Debris erosion is the only area where the debris transport analysis deviates from the regulatory guidance. The guidance specifies that an erosion fraction of 90% should be used for fiberglass debris. However, as described in the justification below, an erosion fraction of 10% was used for fiberglass debris in the recirculation pool.

The only insulation debris with the potential for erosion at STP is the unjacketed small and large pieces of Nukon™ and Thermal-Wrap™ fiberglass.

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 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 STP, however, the break would generate debris that would either be blown to upper containment or blown out away from the break. 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). The erosion mechanism for debris in the pool is somewhat different than what was tested in the DDTS. The SER (Appendix III) describes erosion tests that indicated that the erosion rate of fibrous debris could be on the order of 0.3 percent of the current debris per hour for a pool with a 16-inch depth (compared to 2 percent per hour for a pool with a 9-inch depth). Using the following equation, this gives a total erosion of 7% after 24 hours, and 89% after 30 days.

$$f_{eroded} = 1 - (1 - rate)^{NumberOfHours}$$

where:

f_{eroded} = total fraction of debris eroded
rate = erosion rate of current debris per hour
Number of Hours = Number of hours debris is subject to erosion

The SER points out substantial uncertainties associated with the erosion testing including the following:

- The integral debris transport tests lasted 3 to 5 hours. Therefore, the question remains whether the erosion rate tapers off with time. In addition, it is not certain that all of the end-of-test debris accumulation was the result of erosion products.
- The test results include the usual variances in test data, such as flow and depth control and debris collection.
- Although the test series was designed to approximate the flow and turbulence characteristics of the volunteer-plant sump pool, the tank characteristics may have been significantly different than those at the plant. The difference in the erosion rates between the 9-inch and 16-inch pool depths in the integrated tests clearly illustrates the effect of pool turbulence on fibrous debris erosion.

- The geometry of the volunteer-plant sump pool is larger and more complex than that of the test tank used in the integrated tests.
- The long-term tests did not study large-piece debris.

Since the test data showed in general that the erosion consisted primarily of small, loosely attached pieces of fiber breaking off from larger pieces, it is considered reasonable to assume that erosion would taper off after 24 hours. To be conservative, however, the 24 hour erosion was rounded up to 10%. This erosion fraction was applied to unjacketed large fiberglass pieces in the containment pool.

Content Guide Item 3e. Debris Transport

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

Response

See response in subsection above for first bullet.

Content Guide Item 3e. Debris Transport

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

Response

Debris interceptors are not integrated into the STP debris transport analysis

Content Guide Item 3e. Debris Transport

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

Response

Debris settling is not credited for the STP debris transport analyses. The analysis is a model of transport to the sump.

Content Guide Item 3e. Debris Transport

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

Response

Transport logic trees were developed for each size and type of debris generated. These trees were used to determine the total fraction of debris that would reach the sump screen in each of the postulated cases. The postulated cases include; a break in the Loop C hot leg, a break in reactor cavity, breaks in the RHR and SI pump suction and discharge lines of Loops A and B, a break in the RHR pump suction line of Loop C, and a break in the CVCS letdown line.

Table 21 – Case 1 (Loop C hot leg) debris transport fractions and debris amounts

Debris Type	Debris Size	Debris Generated	Debris Transport Fraction	Debris At Sump
Insulation				
NUKON®	Small Fines	94.4 ft^3	95%	89.7 ft^3
	Large Pieces	62.9 ft^3	1%	0.6 ft^3
	Intact Blankets	139.9 ft^3	0%	0
Thermal-Wrap	Small Fines	143.9 ft^3	95%	136.7 ft^3
	Large Pieces	95.9 ft^3	1%	0.96 ft^3
	Intact Blankets	0	0%	0
Microtherm	Small Fines	4.3 ft^3	95%	4.1 ft^3
Marinite	Small Fines	0		
RMI	Small Pieces (<4")	0		
	Large Pieces (>4")	0		
Qualified Coatings in ZOI				
Epoxy	Fines	23 lbm	95%	21.9 lbm
IOZ	Fines	553 lbm	95%	525 lbm
Polyamide Primer	fines	10 lbm	95%	9.5 lbm
Unqualified Coatings				
Epoxy inside Rx Cavity	Fines and chips	1,714 lbm	0%	0
Epoxy outside Rx Cavity	Fines and chips	294 lbm	48%	141 lbm
Alkyds	fines	247 lbm	100%	247 lbm
IOZ	fines	843 lbm	100%	843 lbm
Baked Enamel	fines	268 lbm	100%	268 lbm
Latent Debris				
Latent Fiber	fines	30 lbm	83%	25 lbm
Dust & Dirt	fines	170 lbm	83%	141 lbm

Table 22 – Case 2 (Reactor cavity) debris transport fractions and debris amounts

Debris Type	Debris Size	Debris Generated	Debris Transport Fraction	Debris At Sump
Insulation				
NUKON®	Small Fines	7.9 ft^3	95%	7.5 ft^3
	Large Pieces	5.3	1%	0.05ft^3
	Intact Blankets	19.8	0%	0
Thermal-Wrap	Small Fines	0		
	Large Pieces	0		
	Intact Blankets	0		
Microtherm	Small Fines	0.9 ft^3	95%	0.86 ft^3
Marinite	Small Fines	15.2 ft^3	83%	12.6 ft^3
RMI	Small Pieces (<4")	18,370 ft^2	31%	5,695 ft^2
	Large Pieces (>4")	6,123 ft^2	31%	1,898 ft^2
Qualified Coatings in ZOI				
Epoxy	Fines	23 lbm	83%	19.1 lbm
IOZ	Fines	553 lbm	83%	459 lbm
Polyamide Primer	fines	10 lbm	83%	8.3 lbm
Unqualified Coatings				
Epoxy inside Rx Cavity	Fines	1,714 lbm	83%	1,423 lbm
Epoxy outside Rx Cavity	Fines and chips	294 lbm	48%	141 lbm
Alkyds	fines	247 lbm	100%	247 lbm
IOZ	fines	843 lbm	100%	843 lbm
Baked Enamel	fines	268 lbm	100%	268 lbm
Latent Debris				
Latent Fiber	fines	30 lbm	83%	25 lbm
Dust & Dirt	fines	170 lbm	83%	141 lbm

Table 23 –RHR suction line of Loop B (bounding for suction lines) debris transport fractions and debris amounts

Debris Type	Debris Size	Debris Generated	Debris Transport Fraction	Debris At Sump
Insulation				
NUKON®	Small Fines	9.8 ft^3	95%	9.3 ft^3
	Large Pieces	6.5 ft^3	1%	0.07ft^3
	Intact Blankets	1.6 ft^3	0%	0
Thermal-Wrap	Small Fines	0		
	Large Pieces	0		
	Intact Blankets	0		
Microtherm	Small Fines	0		
Marinite	Small Fines	0		
RMI	Small Pieces (<4")	0		
	Large Pieces (>4")	0		
Qualified Coatings in ZOI				
Epoxy	Fines	23 lbm	100%	23 lbm
IOZ	Fines	553 lbm	100%	553lbm
Polyamide Primer	fines	10 lbm	100%	10 lbm
Unqualified Coatings				
Epoxy inside Rx Cavity	Fines	1,714 lbm	0%	0 lbm
Epoxy outside Rx Cavity	Fines and chips	294 lbm	45%	132 lbm
Alkyds	fines	247 lbm	100%	247 lbm
IOZ	fines	843 lbm	100%	843 lbm
Baked Enamel	fines	268 lbm	100%	268 lbm
Latent Debris				
Latent Fiber	fines	30 lbm	83%	25 lbm
Dust & Dirt	fines	170 lbm	83%	141 lbm

Table 24 –SI Discharge line of Loop B (bounding for discharge lines) debris transport fractions and debris amounts

Debris Type	Debris Size	Debris Generated	Debris Transport Fraction	Debris At Sump
Insulation				
NUKON®	Small Fines	1.3 ft^3	95%	1.2 ft^3
	Large Pieces	0.9 ft^3	1%	0.01ft^3
	Intact Blankets	0	0%	0
Thermal-Wrap	Small Fines	0		
	Large Pieces	0		
	Intact Blankets	0		
Microtherm	Small Fines	0		
Marinite	Small Fines	0		
RMI	Small Pieces (<4")	0		
	Large Pieces (>4")	0		
Qualified Coatings in ZOI				
Epoxy	Fines	23 lbm	100%	23 lbm
IOZ	Fines	553 lbm	100%	553 lbm
Polyamide Primer	fines	10 lbm	100%	10 lbm
Unqualified Coatings				
Epoxy inside Rx Cavity	Fines	1,714 lbm	0%	0 lbm
Epoxy outside Rx Cavity	Fines and chips	294 lbm	45%	132 lbm
Alkyds	fines	247 lbm	100%	247 lbm
IOZ	fines	843 lbm	100%	843 lbm
Baked Enamel	fines	268 lbm	100%	268 lbm
Latent Debris				
Latent Fiber	fines	30 lbm	83%	25 lbm
Dust & Dirt	fines	170 lbm	83%	141 lbm

Table 25 – RHR pump suction line of Loop A debris transport fractions and debris amounts

Debris Type	Debris Size	Debris Generated	Debris Transport Fraction	Debris At Sump
Insulation				
NUKON®	Small Fines	6.9 ft^3	95%	6.6 ft^3
	Large Pieces	4.6 ft^3	1%	0.05ft^3
	Intact Blankets	4.0 ft^3	0%	0
Thermal-Wrap	Small Fines	0		
	Large Pieces	0		
	Intact Blankets	0		
Microtherm	Small Fines	0		
Marinite	Small Fines	0		
RMI	Small Pieces (<4")	0		
	Large Pieces (>4")	0		
Qualified Coatings in ZOI				
Epoxy	Fines	23 lbm	100%	23 lbm
IOZ	Fines	553 lbm	100%	553 lbm
Polyamide Primer	fines	10 lbm	100%	10 lbm
Unqualified Coatings				
Epoxy inside Rx Cavity	Fines	1,714 lbm	0%	0 lbm
Epoxy outside Rx Cavity	Fines and chips	294 lbm	45%	132 lbm
Alkyds	fines	247 lbm	100%	247 lbm
IOZ	fines	843 lbm	100%	843 lbm
Baked Enamel	fines	268 lbm	100%	268 lbm
Latent Debris				
Latent Fiber	fines	30 lbm	83%	25 lbm
Dust & Dirt	fines	170 lbm	83%	141 lbm

Table 26 – CVCS letdown line debris transport fractions and debris amounts

Debris Type	Debris Size	Debris Generated	Debris Transport Fraction	Debris At Sump
Insulation				
NUKON®	Small Fines	1.1 ft^3	95%	1.05 ft^3
	Large Pieces	0.7	1%	0.007ft^3
	Intact Blankets	0.8	0%	0
Thermal-Wrap	Small Fines	0		
	Large Pieces	0		
	Intact Blankets	0		
Microtherm	Small Fines	0		
Marinite	Small Fines	0		
RMI	Small Pieces (<4")	0		
	Large Pieces (>4")	0		
Qualified Coatings in ZOI				
Epoxy	Fines	23 lbm	95%	21.9 lbm
IOZ	Fines	553 lbm	95%	525 lbm
Polyamide Primer	fines	10 lbm	95%	9.5 lbm
Unqualified Coatings				
Epoxy inside Rx Cavity	Fines and chips	1,714 lbm	0%	0
Epoxy outside Rx Cavity	Fines and chips	294 lbm	41%	121 lbm
Alkyds	fines	247 lbm	100%	247 lbm
IOZ	fines	843 lbm	100%	843 lbm
Baked Enamel	fines	268 lbm	100%	268 lbm
Latent Debris				
Latent Fiber	fines	30 lbm	83%	25 lbm
Dust & Dirt	fines	170 lbm	83%	141 lbm

Content Guide Item 3f. Head Loss and Vortexing

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

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

Content Guide Item 3f. Head Loss and Vortexing

- *Provide a schematic diagram of the emergency core cooling system (ECCS) and containment spray systems (CSS).*

Response

See Figure 7 below for schematic with elevation layout.

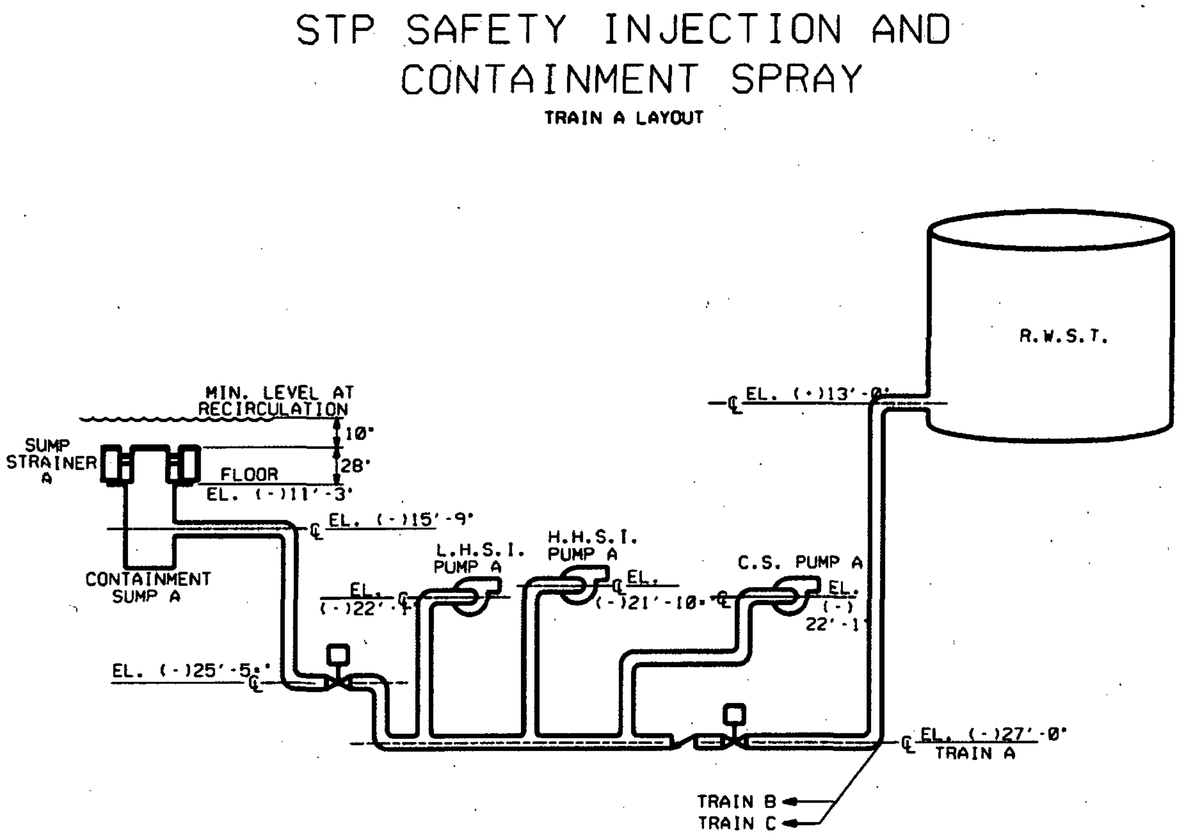


Figure 7 – ECCS Schematic

Content Guide Item 3f. Head Loss and Vortexing

- *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.*

Response

For the SBLOCA low water condition, the strainer has ½ in. submergence. For the LBLOCA at the start of recirculation, the minimum water level provides the strainer with 10 in. submergence.

Content Guide Item 3f. Head Loss and Vortexing

- *Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions.*

Response

<u>Methodology</u>

The calculation utilized standard hydraulic principles and equations to address the subject issues. The calculation conservatively assumed that each issue is separate, and each issue was addressed on its own merits.

Assumptions

Conservatively, the sump fluid is assumed to be saturated at the surface of the pool at the pressure that corresponds to the sump temperature during the LOCA or post-LOCA period for temperatures at or above 212 °F. No credit for sub-cooling of the sump fluid is assumed with regard to head-loss, vortex, air ingestion, or void fraction determination in accordance with various USNRC guidance documents, specifically RG 1.1.

A flow velocity of 0.009 fps for the strainer, through a debris bed consisting of fibers and particulate, is 100% viscous flow. Accordingly, the head loss is linearly proportional to dynamic viscosity.

A scale strainer, which is designed to maintain the same approach velocity as the full scale production strainer, can accurately simulate the performance of the full scale production strainer so long as the same scaling factor is used for strainer area, water flow rate, and debris quantities. The scaling factor is defined as ratio of the surface area of the scale strainer and the surface area of the full scale production strainer.

To adjust the measured head loss across a debris bed with colder water, a ratio of water viscosities, between the warmer specified post-LOCA water temperature and the colder test temperature, can be multiplied by the measured head loss to obtain a prediction of the head loss with water at the specified post-LOCA temperature.

Results

Vortexing – Based on the design configuration of the strainer assembly, the largest opening for water to enter into the sump is through the perforated plate 0.095" holes. The size of the perforated plate holes by themselves would preclude the formation of a vortex. However, in the unlikely event that a series of "mini-vortices" combined in the interior of a disk to form a vortex the combination of the wire stiffener "sandwich" and the small openings and passages that direct the flow of water to the strainer core tube would further preclude the formation of a vortex in either the core tube or the sump.

Testing with a conservative low water level has shown that vortexing would not occur.

Air Ingestion – The guidance of RG 1.82 Rev. 3 was used to address air ingestion. Sump performance specifically related to air ingestion is a strong function of the Froude Number, Fr. By limiting the Froude Number to a maximum of 0.25. air ingestion can be maintained to <2%.

The calculated Froude Number for the STP PCI Sure Flow® suction strainer is 0.459 (slightly higher than the USNRC guidance found in RG 1.83). However, due to the combination of a low Froude Number and lack of an air entrainment mechanism (i.e., vortex formation) in conjunction with the complete submergence of the strainer, air ingestion is not expected to occur.

Void Fraction – Void formation is the result of the pressure of a fluid being reduced below the saturation pressure with the resulting voids being formed by the flashing of the liquid phase. Air does not need to be present to create significant voiding.

The calculation evaluated the issue of Void Fraction by the use of conventional hydraulic and fluid flow calculations to determine the Void Fraction and concluded that flashing and subsequent void fraction formation would not occur across the strainer.

Content Guide Item 3f. Head Loss and Vortexing

- *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.*

Response

Purpose and Description

The testing of the PCI strainer was performed by PCI and its sub-contractors Areva NP and Alden Research Laboratory at the Alden facility in Massachusetts during July 2008. The purpose of the test was to measure the head loss across the strainer based on prototypical water flow and debris mix conditions expected in the containment sump following a postulated LOCA. The test strainer was a module identical to those installed in the STP containment.

Two tests were performed:

Test 1 - Clean Strainer Head Loss Test

This determined the head loss of a clean strainer which will be subtracted from the next test results to yield the debris bed head loss.

Test 2 - Debris Loaded Strainer Head Loss Test (Design Basis)

This determined the debris bed head loss for a bounding scenario for South Texas where the maximum quantity of each debris type is used. After completing the test, the strainer was observed to have a debris bed approximately 0.75 in. thick of which over 95% consisted of chemical debris. A small amount of fiber was observed on the strainer. However, this quantity was very small and could not be measured with a standard tape measure. (See photo at end of this section.) Since the fiber quantity was significantly less than 0.125 in. thick, it was concluded that a separate thin bed test would not need to be performed.

Differences from Previous Testing

Previous testing was performed in February 2008 which yielded unacceptable head loss results. Refinements to the debris generation and debris transport calculations were made which resulted in a decreased fiber loading and a decreased coating particulate loading. The February test used walnut flour as a surrogate for coating particulates. For the July test, acrylic powder and chips were used instead. Also, the February test used Cal-Sil as a surrogate for Marinite insulation. The July test used Marinite powder.

Test Apparatus

The test apparatus at the Alden facility included the large test flume, two pumps, test strainer module, instrumentation and controls, associated piping for the recirculation loop with two pumps in parallel, chemical mixing tanks, a pump to add the chemical debris into the flume, and associated piping and tubing. To maintain a constant water level during testing, an overflow pipe set at the proper water elevation was used. Debris which flowed into the overflow pipe was captured by 10 micron bag filters. This debris captured by the bag filters was periodically flushed to return the debris back to the test flume.

The test flume measured 10 ft wide by 5 ft deep and 45 ft long. Inside of the steel flume, plywood was used to contour the flume walls to simulate the approach velocities expected near the sump inside containment. A heat recirculation loop with a heat exchanger was used to heat the test water to 120 F. After the initial heat up, immersion heaters were used to maintain the temperature.

Scales were used to weigh the debris in a dry state before introduction into the flume.

Downstream sampling capability was provided by three isokinetic sampling ports and associated piping. The samples were taken downstream of the test strainer and upstream of the recirculation pumps.

Test Strainer

The strainer module is a full size module that is identical to those installed inside the STP containment building. The test strainer has a surface area of 91.44 sq ft. The test flow rate and debris quantities were scaled down based on the surface area of the strainer. The test flow rate was 353 gpm. The velocity through the strainer module was 0.0086 ft/sec.

Test Debris

Reflective Metallic Insulation (RMI) was not used for the July 2008 testing since prior testing in February showed that stainless steel RMI pieces of various sizes (0.25 in. x 0.25 in. up to 4 in. x 4 in.) did not transport in the test flume. It is conservative not to include it in the head loss testing since it would tend to entrap other debris to prevent them from reaching the strainer.

Coatings that exist as potential debris are zinc top coat, epoxy coatings, polyamide primer coatings, alkyd coatings, and baked enamel coatings. Tin powder was used as a surrogate for zinc since zinc is considered a hazardous material by the Commonwealth of Massachusetts. Pulverized acrylic coating powder was used as a surrogate material for the epoxy coatings, polyamide primer coatings, alkyd coatings, and baked enamel coatings. Acrylic chips were used as the surrogate material for the epoxy chips.

Miscellaneous debris such as lead blanket pieces and tags and labels were not included in the July testing since it was shown in the February testing that these items did not transport. It is conservative not to include it in the head loss testing since it would tend to entrap other debris to prevent them from reaching the strainer.

Fibers debris consists of NUKON insulation, Thermal Wrap insulation, and latent fibers. NUKON fibers were used for testing for the NUKON insulation and the latent fiber debris. Knauf ET fibers were used for the Thermal Wrap insulation fibers.

Besides coatings debris consisting of particulates, other particulate debris inside containment includes Marinite powder, Microtherm powder, and latent dirt and dust. For the testing, Marinite powder and Microtherm powder were used. The latent dirt and dust debris was simulated by a dirt mix of various sizes of Silica sands.

The chemical debris determined to be in the containment sump are Sodium Aluminum Silicate, Aluminum Oxyhydroxide, and Calcium Phosphate. The amounts are conservatively based on a 30 spray duration. The testing used chemical precipitates that were generated utilizing the methodology in WCAP-16530-NP and final SER, WCAP-16785-NP, and PWROG letter OG-07-270. The chemical materials were generated in mixing tanks and introduced into the test flume within the parameters provided in PWROG letter OG-07-270.

Since the production of Sodium Aluminum Silicate is considered hazardous based on Section 7.3.2 of WCAP-16530-NP Rev. 0, Aluminum Oxyhydroxide was generated in accordance with the directions in Section 7.3.2 of WCAP-16530-NP for strainer testing when either Aluminum Oxyhydroxide or Sodium Aluminum Silicate was required. This is acceptable since Section 7.3.2 of WCAP-16530-NP Rev. 0 states that the characteristics of Sodium Aluminum Silicate are sufficiently similar to Aluminum Oxyhydroxide. Thus Aluminum Oxyhydroxide was used in lieu of Sodium Aluminum Silicate.

Debris Preparation and Sequencing

The NUKON and Knauf fibers were weighed dry in buckets or large trash cans. The fine fibers, latent fibers, and eroded large fibers were shredded using a food processor. The small fibers were processed using a wood chipper. The small fibers were sifted through a 1 in. x 4 in. grate where the small fibers would sift through the grate. The fine fibers contained within the small fibers were removed from the small fibers.

The particulate and fiber debris was weighed dry in buckets and then mixed with heated water to remove air that may have been entrained in the debris.

Prior to starting the recirculation pump, 25% of the latent fiber load was distributed uniformly in the flume upstream of the strainer. Five minutes later the pump was started. After 2 pool turnovers, a debris batch with all of the particulates and chips and most of the fine fibers was added. Each debris type was introduced into the flume from an individual bucket or can during the batch step. After head loss stabilized (39 minutes later) a debris batch with the chips and small fiber insulation was added. Again after head loss stabilized (34 minutes later), Debris Batch #4 with the fiber fines from large piece erosion was added. The test continued to run overnight with no further debris introductions. The first chemical batch was introduced the next day followed by 32 more chemical batches. A waiting time of 1 or 2 pool turnovers followed each chemical batch depending upon the particular chemical being added.

Methodology

The flume wall configuration was determined by using a computational fluid dynamics (CFD) model that determined the approach velocities in the vicinity of the sump. A localized CFD model was used to define the approach velocities to each strainer array installed in the containment by calculating average velocities at incremental distances from the end of the strainer arrays. Weighted average velocities were used to yield the approach velocities to the test strainer. The flume walls were configured to obtain this velocity profile leading to the test strainer.

The clean strainer head loss test took pressure drop readings for five flow rates in the operating range of 176 gpm to 530 gpm.

The headloss due to the debris blockage on the strainer was determined by subtracting the velocity head at the downstream pressure taps and clean strainer head loss from the pressure drop measured between these taps and the flume water surface.

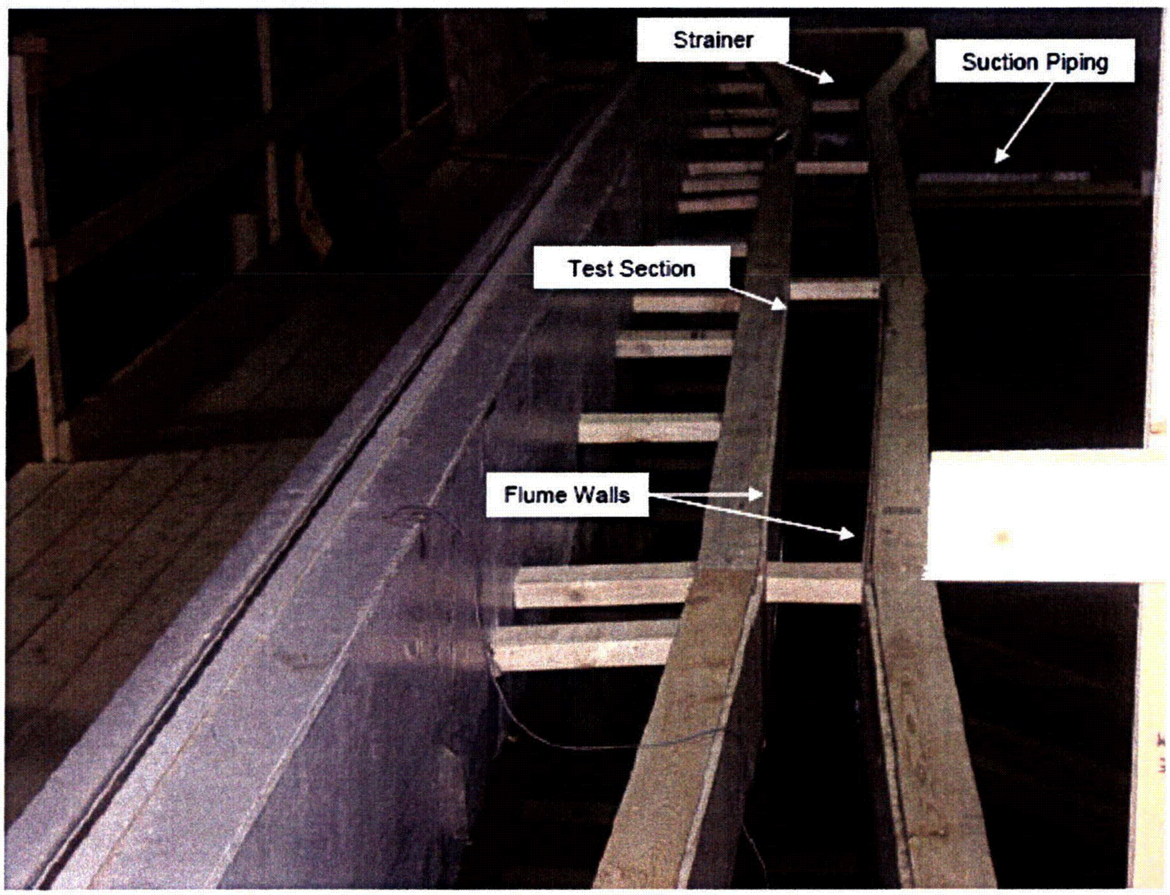
Throughout the test when debris was not being added to the flume, the head loss tended to trend slowly downward. Since the head loss continually depleted with respect to time, the maximum head loss value observed during the test is bounding of the head loss value that could be extrapolated using the data collected during the last 15 pool turnovers of the test.

Results

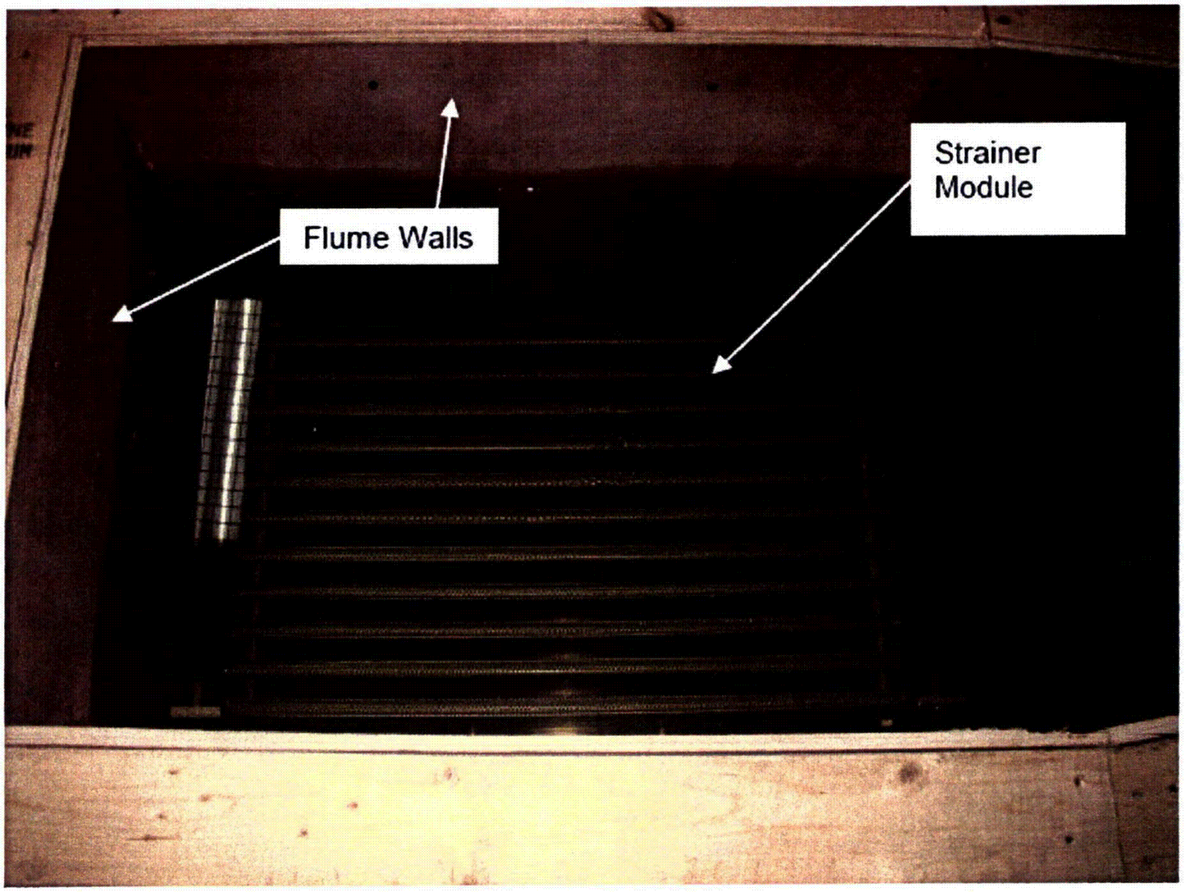
The clean strainer head loss for a flow of 353 gpm was 0.0923 ft. at a temperature of 116.3 F.

For the design basis debris test, the maximum corrected head loss (excluding clean strainer head loss and piping losses) was 8.745 ft. at a flow rate of 355.857 gpm at a corrected temperature of 116.3 F. Since a fiber bed less than 1/8 in. thick was observed after the end of the test during drain down, it was concluded that a thin bed test was not required. It was noted that the head loss was decreasing with respect to time at the end of the test and that an extrapolated head loss was not required. No vortices or bore holes were observed during testing.

Photos



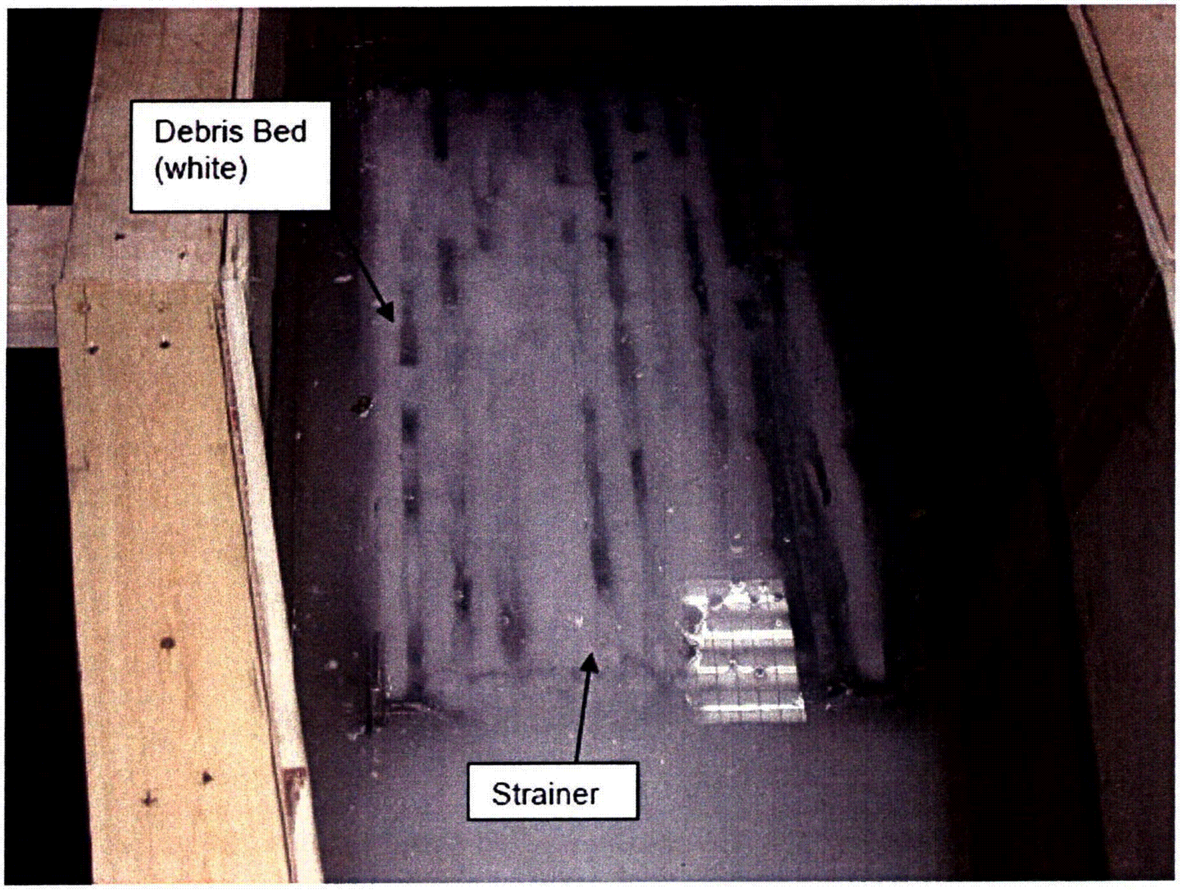
Test Flume



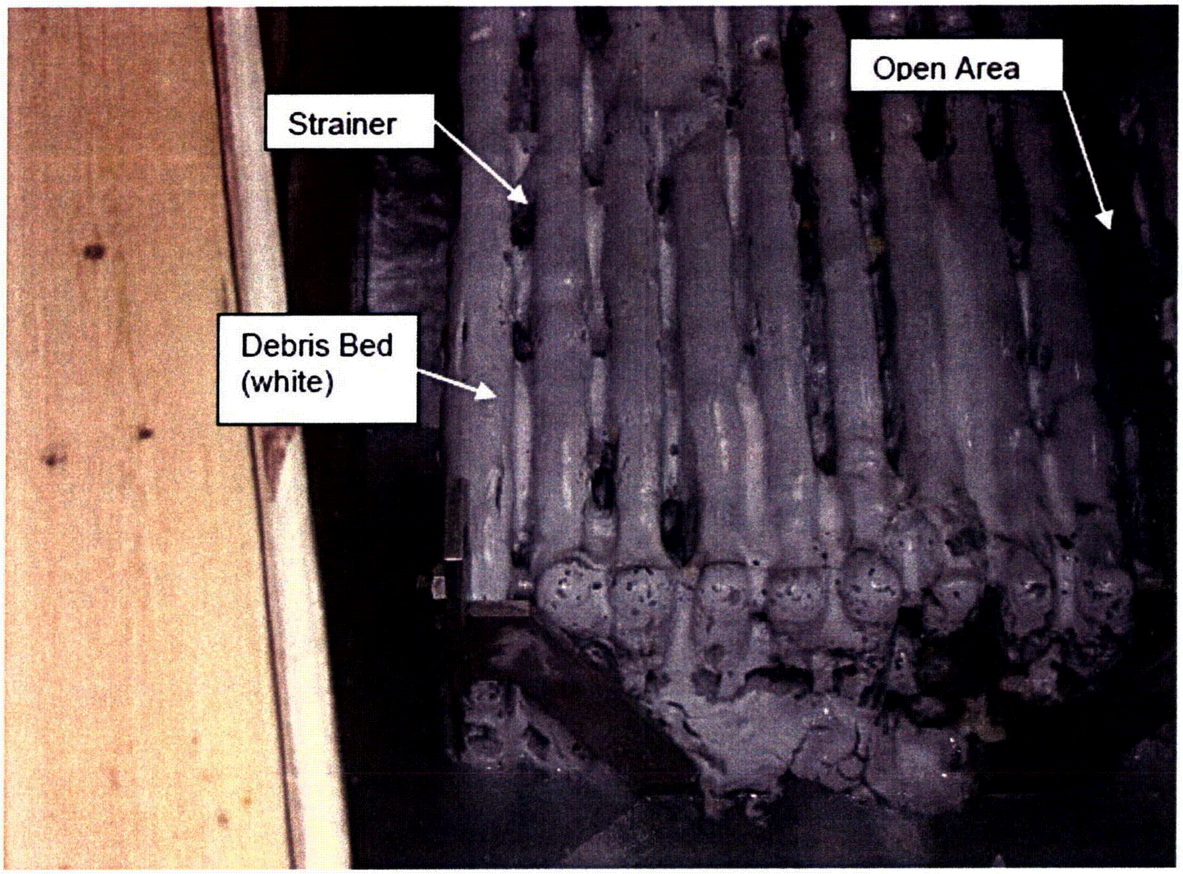
Test Strainer Module in Test Flume

Debris Introduction

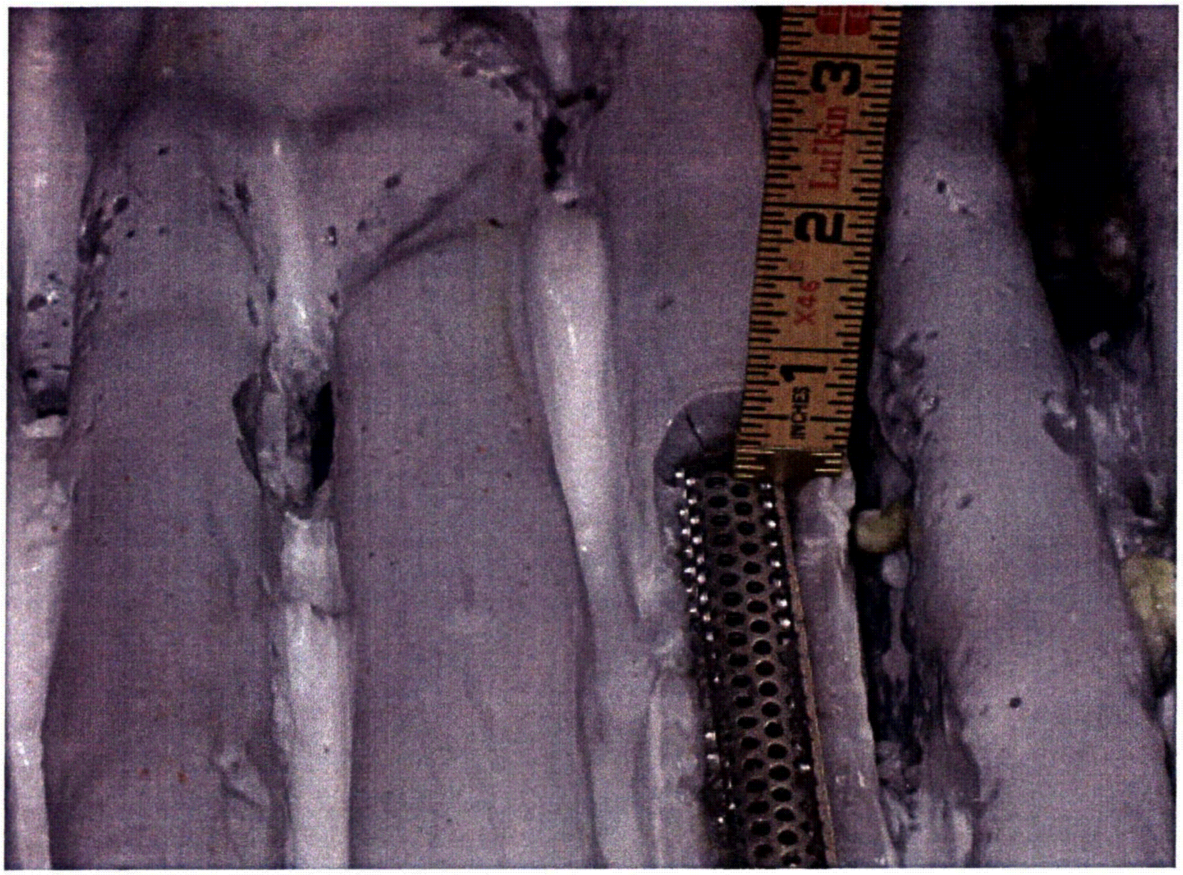
Chemical Debris Preparation Tanks



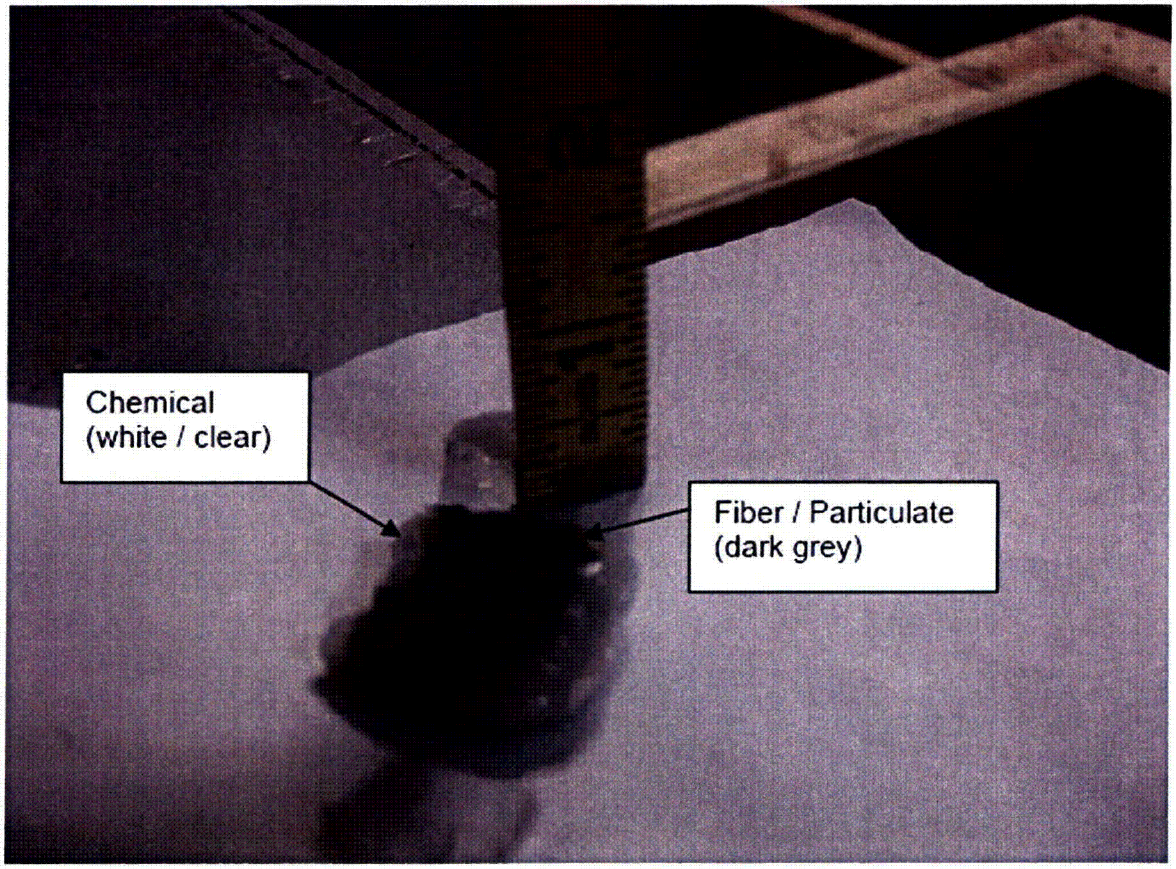
\Strainer During Drain Down



Close-up Strainer During Drain Down



Debris Bed Thickness



Debris Bed Sample

Content Guide Item 3f. Head Loss and Vortexing

- *Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen.*

Response

The head loss testing of the strainer in the laboratory shows that the strainer has acceptable performance for the design basis test that uses the maximum amounts of debris that are determined to be transported to the sump strainers. The testing is further discussed in the section above.

Content Guide Item 3f. Head Loss and Vortexing

- *Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial thin bed formation.*

Response

Debris head loss testing of the sump strainer in the laboratory showed that a "thin bed" was not achieved during the design basis test. After completion of the test, the flume was drained down in order to observe the debris bed on the strainer module. The debris bed was approximately 3/4 in. thick. Analysis of a sample of the debris bed showed that over 95% of the debris bed consisted of chemical debris. A small amount of fiber was observed on the surface of the strainer. However, the quantity of this fiber was very small and could not be measured with a standard tape measure. It was concluded that since the fiber quantity was significantly less than 1/8 in. thick, a separate thin bed test would not be performed. Thus the testing showed that the strainer resists the formation of a thin bed.

Content Guide Item 3f. Head Loss and Vortexing

- *Provide the basis for the strainer design maximum head loss.*

Response

The head loss testing of the strainer in the laboratory forms the basis for the design maximum head loss.

Content Guide Item 3f. Head Loss and Vortexing

- *Describe significant margins and conservatisms used in the head loss and vortexing calculations.*

Response

The head loss analysis is based on laboratory testing rather than a calculation. The testing is discussed in a section above.

The margins and conservatisms in the vortexing calculations include;

- no credit is taken for containment over pressurization
- verification that the minimum ½ in. submergence of the South Texas Project sump strainers will preclude air ingestion or vortex development by strainer prototype testing at Alden Research Laboratory.
- limiting the Froude number to a maximum of 0.25, while maintaining air ingestion at <2% which is the value used in RG 1.82 Rev. 3.

Content Guide Item 3f. Head Loss and Vortexing

- *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation.*

Response

The calculation utilized two (2) distinct methodologies based on the entire strainer assembly configuration in determining the Clean Strainer Head loss: (1) strainer and (2) pipe and fittings. The first methodology for strainer only head loss, employed an equation that was experimentally derived, and which was used to determine the strainer head loss contribution. The second methodology utilized classical standard hydraulic head loss equations based on Crane Technical Paper 410 for pipe and fittings that were used to determine the total head loss contributions of the strainer attached pipe and fittings. The individual head loss results from the strainer and the pipe fittings were added together to obtain the head loss for the entire strainer assembly configuration.

An increase of 10% for connecting pipe and fitting head loss calculations, is adequate to address any non-conservatism inherent in the use of standard head loss correlations.

An increase correction of 6% of the clean strainer head loss is to account for uncertainty.

In order to determine the greatest Clean Head Loss for the strainer, the minimum post-LOCA sump recirculation temperature of 128°F was utilized.

The result of this calculation, specifically the Total Corrected Clean Strainer Head Loss value, is calculated to be 1.95 feet of water. The calculation and supporting portions thereof, considered all of the previous testing that has been performed for the various PCI Sure-Flow™ Suction Strainer prototypes, including uncertainty.

Content Guide Item 3f. Head Loss and Vortexing

- *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis.*

Response

The debris head loss analysis is based on the laboratory testing of the strainer module. The HLOSS computer code was used in the initial evaluation of the sump performance; but this code is not considered valid for use for the new strainer design installed at South Texas.

The methodology for the head loss analysis consists of the clean strainer head loss determination and the head loss test results. These are added together to yield the total design basis head loss for the installed strainer array. The values are first temperature adjusted for the post-LOCA temperature condition before adding.

The flow velocity for the strainers is 0.009 ft/sec which is considered as 100% viscous flow through the debris bed. Thus the head loss is linearly proportional to dynamic viscosity.

For the 24 hour post-LOCA temperature of 171 F, the resulting Total strainer head loss is 6.504 ft

Content Guide Item 3f. Head Loss and Vortexing

- *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.*

Response

The strainers are fully submerged for SBLOCA and LBLOCA conditions.

Content Guide Item 3f. Head Loss and Vortexing

- *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.*

Response

Near Field Settling

The strainer head loss testing did credit near-field settling. The test flume was constructed with the flume walls arranged such that the velocity fields around the testing strainer were representative or bounding of the expected velocity fields in the containment during LOCA recirculation. Two computational fluid dynamics (CFD) analyses were used to accurately model the debris transport and to model the flow/turbulence of the flow patterns approaching the strainer.

A refined CFD analysis near sump screen structure was performed to model the flow patterns approaching the sump to define approach flow velocities for the test flume. The CFD analysis completed for the transport calculation modeled the sump as a mass sink, which was not based on the actual strainer design configuration.

The refined analysis was required because the debris transport CFD simulation utilized a relatively coarse mesh in the vicinity of the sump pits. The boundary condition at the sump pit in the debris transport CFD model was representative of the plant configuration prior to installation of the Performance Contracting, Inc. (PCI) Sure-Flow® strainer arrays. The flow patterns approaching the perimeter of the pit were strongly influenced by the outflow boundary condition used in the debris transport (CFD) analyses, and the uniform flow characteristics of the PCI Sure-Flow® strainer modules influence the approach flow patterns to the sump.

Inflow boundary conditions for the new near field approach CFD model were taken directly from the results database of the debris transport CFD model (flow and velocity). Water surface elevation was assumed constant.

Flow patterns from the refined new near field approach CFD model reflect the presence of the PCI Sure-Flow® Strainer Array. Flow patterns approaching the sump pit from the containment periphery were similar in the two CFD calculations.

The new near field approach CFD flow patterns and velocities are more representative of the post LOCA containment flow patterns because the boundary conditions associated with the PCI Sure-Flow® Strainer have been included in the analysis, and the computational grid has been greatly refined in the vicinity of the sumps resulting in a more realistic prediction of approach flow patterns near the sump pit and strainers.

Content Guide Item 3f. Head Loss and Vortexing

- *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.*

Response

Temperature/viscosity was used to scale the results of the head loss tests to the expected post-LOCA plant conditions. At the conclusion of the head loss testing at the laboratory, flow sweeps were conducted to show that no bore holes were present. The flow rate was reduced to approximately half of the design flow rate and the head was allowed to stabilize. Then the flow was adjusted back to the design flow rate. No vortices or bore holes were observed during the testing. Thus the testing provided the basis for concluding that bore holes or other differential-pressure induced effects did not affect the morphology of the test debris bed.

Content Guide Item 3f. Head Loss and Vortexing

- *State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure.*

Response

Containment accident pressure is not credited.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

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

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

- *Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.*

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level.*

Response

The design flow per sump for LBLOCA is 7,020 gpm. Two of the three sumps are assumed to be operating due to single failure of the diesel for the third train. The flows for the pumps in each operating train are:

LHSI 2,800 gpm HHSI 1,620 gpm CS 2,600 gpm

The sump temperature at start of recirculation is 267 degrees F.

The minimum containment water level at start of recirculation is 38 in. off the floor.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions.*

Response

The SI pump flow rates are the maximum values given in the Technical Specifications. The CS pump flow rate is based on calculated maximum flows when two trains are operating. The sump temperature is from the containment LOCA pressure-temperature analysis which maximizes the sump temperature by using the maximum temperatures for cooling water to the heat exchangers and for the water of the ultimate heat sink. The containment water level was determined using conservative input values for the pool contributions and conservatively accounting for items such as holdup in locations in the containment, filling of empty pipe, water in transit, steam holdup, etc.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Provide the basis for the required NPSH values, e.g., three percent head drop or other criterion.*

Response

Westinghouse supplied the LHSI, HHSI, and CS pumps to STP from Pacific Pumps. The required NPSH values are based on input from Westinghouse and are as follows:

LHSI 16.5 ft. HHSI 16.1 ft. CS 16.4 ft.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Describe how friction and other flow losses are accounted for.*

Response

The strainer modification did not change the piping friction losses used in the NPSH calculation. The friction losses are based on the maximum flows of the SI and CS pumps.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Describe the system response scenarios for LBLOCA and SBLOCA's.*

Response

For LBLOCA the Safety Injection Pumps and the Containment Spray Pumps start automatically and take suction from the Refueling Water Storage Tank. When the tank is drawn down, the pumps' suction is automatically switched over to the containment sumps for the recirculation mode. The HHSI and CS Pumps may be turned off later in the post-accident mitigation per the emergency operating procedures.

For SBLOCA the HHSI Pump is used for the core cooling function during the injection and the recirculation phases. The CS pump is also assumed to be in operation due to automatic actuation by reaching the containment pressure set point.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation.*

Response

Both before and after the initiation of recirculation, two Trains are operating. Each Train consists of one HHSI, one LHSI, and one CS pump. Each Train has its own containment sump with strainer.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Describe the single failure assumptions relevant to pump operation and sump performance.*

Response

The STP design has three safety Trains each with its own containment sump. The sump performance analysis is based on a single failure that results in two Trains operating to handle the debris generated.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Describe how the containment sump water level is determined.*

Response

The Containment Water Level Calculation analyzed multiple high-energy line break cases including large break and small break LOCA's chosen to encompass a wide range of potential break sizes and locations. The breaks were analyzed at various times throughout the event including at the start of recirculation, at suspension of containment sprays and at the end of the event. The following methodology was used to develop the Containment Water Level Calculation:

1. A correlation was developed for the relationship between containment water level and the containment volume as a function of elevation using information from existing STP calculations. The correlation between containment volume and water level developed in the Water Level Calculation assumes equalization of water level between all areas of containment at the (-)11'-3" elevation including internal compartments (e.g., incore instrument room, reactor cavity and elevator shaft). The volume inside the accumulator skirts is only credited as a displacement volume for the small break LOCA case in which the water level does not reach the service way openings preventing this volume from filling. The correlation also includes all volumes below the (-)11'-3" elevation (e.g., elevator shaft, normal sump, secondary normal sump, emergency sumps, incore instrument room sump and drain lines).

2. The quantity of water added to containment from the Refueling Water Storage Tank, SI Accumulators, and the Reactor Coolant System was determined for each of the breaks considered.

3. The quantity of water diverted from the containment sump was determined. The following effects were considered:

- Steam holdup in the containment atmosphere
- Additional mass of water that must be added to the RCS due to the increase in the water density at the lower sump water temperature versus the RCS temperature prior to the LOCA
- Water volume required to fill the RCS steam space as condensation occurs
- Condensation on containment surfaces
- Water volume required to fill the Safety Injection and Containment Spray Piping that is empty prior to the LOCA
- Water in transit from the Containment Spray nozzles and the break location to the Containment Sump
- ECCS leakage outside of containment
- Miscellaneous hold-up volumes throughout containment

4. Given the net mass of water added to the containment floor based on items 2 and 3 listed above, the post-LOCA containment water level was then calculated using the correlation developed in item 1.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Provide assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin.*

Response

See subsection immediately above.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *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.*

Response

See subsection immediately above.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Provide assumptions (and their bases) as to what equipment will displace water resulting in higher pool level.*

Response

See subsection immediately above.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

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

Response

See subsection immediately above.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *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.*

Response

Containment accident pressure is not credited for available NPSH.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature.*

Response

Containment accident pressure is not credited for available NPSH.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.*

Response

Containment accident pressure is not credited for available NPSH.

Content Guide Item 3g. Net Positive Suction Head (NPSH)

- *Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.*

Response

For the start of recirculation temperature of 267 F and the 24 hour post-LOCA temperature of 171 F, the NPSH margin results are:

PUMP	NPSH Margin, ft Start of Reirc.	NPSH Margin, ft 24 hour post-LOCA
LHSI	1.578	2.733
HHSI	1.772	3.069
CS	1.288	2.230

Content Guide Item 3.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.*

Content Guide Item 3.h - Coatings Evaluation

- *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.*

Response

The qualified coatings inside the Unit 1 and Unit 2 Reactor Containments are detailed in STP calculations. There are various types of qualified coatings used in the containment including Ethyl Silicate Inorganic Zinc (IOZ), Epoxy System, Phenolic Epoxy, Clear Sealer, Alkyd, Baked Enamel and Epoxy Intumescent.

The unqualified coatings inside the Unit 1 and Unit 2 Reactor Containments are detailed in STP calculations. There are various types of unqualified coatings used in the containment including IOZ, Epoxy System, Phenolic Epoxy, Alkyd and Baked Enamel.

The following is a brief summary of specific equipment and their coatings; the concrete walls are coated with an Epoxy System, the equipment (valves) are coated with IOZ, whip restraints are coated with Epoxy, the equipment supports are coated with IOZ, the pipe supports are coated with both Polyamide Primer (an epoxy coating) and IOZ.

Content Guide Item 3.h - Coatings Evaluation

- *Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.*

Response

The methodology utilized for the STP debris transport analysis is described above in another section. The transport of containment coatings was included in the analyses. In addition to the methodology described above, the following key attributes apply and are intended to describe and provide the bases for assumptions made in post-LOCA paint debris transport analysis.

1. It was assumed that the settling velocity of fine debris (insulation, dirt/dust, and 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).

2. 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.

3. Both the qualified coatings (inside the ZOI) and the unqualified coatings were conservatively assumed to fail as 10 micron particulate in the debris generation analysis.

The results of debris transport are included in the section above and include the associated values for the transport of coatings debris both within and outside the ZOI. A review of Table 21 through 26 identify that for the bounding LOCA analyses, coating debris transports as fines and 45% - 100% are transported to the screen, depending on the case.

Content Guide Item 3.h - Coatings Evaluation

- *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.*

Coating surrogate material

Response

Strainer head loss testing was conducted in the laboratory to demonstrate acceptable performance with the design basis debris loading. In lieu of the actual coating debris material, surrogate materials were used. The qualified and unqualified coating debris consists of zinc, epoxy coatings, polyamide primer coatings, alkyd coatings, and baked enamel coatings. The epoxy coating debris consists of chips and particulates. The rest of the coating debris is particulates.

Tin powder was used as a surrogate material that substituted for zinc. Pulverized acrylic coating powder was used as a surrogate material for the epoxy coatings, the polyamide primer coatings, the alkyd coatings, and the baked enamel coatings. Acrylic coating chips were used as a surrogate material for the epoxy coating chip debris.

Content Guide Item 3.h - Coatings Evaluation

- *Provide bases for the choice of surrogates.*

Response (B)

All of the surrogate materials are acceptable for the testing since they have similar density, size, and shape characteristics as the debris material. Tin powder was used as a surrogate material for zinc since zinc is considered a hazardous material by the Commonwealth of Massachusetts where the test facility is located. The use of tin powder precludes post-test disposal problems.

Content Guide Item 3.h - Coatings Evaluation

- *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.*

Response

The methodology utilized for the STPEGS debris generation analyses is described in sections above. The generation of containment coating debris was included in the analyses. In addition to the methodology described in these sections, the following key attributes apply and are intended to describe and provide the bases for coatings debris generation assumptions for STPEGS, and describe how the quantity of paint debris was determined based on ZOI size for qualified and unqualified coatings.

All coatings, qualified and unqualified, within the ZOI are assumed to fail and generate debris in the form of 10μm spherical particles, which is equivalent in size to the average zinc particle in inorganic zinc (IOZ) coatings or the pigment used in epoxy coatings.

Qualified Coatings

The assumption made for coatings in the zone of influence (ZOI) of the LOCA is based on testing performed on representative coating systems. A spherical ZOI of 5D for qualified coatings was selected based on refined analysis in WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA Qualified/Acceptable Coatings", Revision 0. This was developed and performed in order to identify an appropriate ZOI for DBA-Qualified / Acceptable coating systems less than the 10D ZOI mandated by the NRC SER on NEI 04-07. The results of this program demonstrate that a ZOI radius of 5D should be used for epoxy and untopcoated inorganic zinc coatings.

Per NEI 04-07, qualified coatings within the ZOI are assumed to fail as a result of impingement and post-accident environmental conditions. Qualified coatings outside the ZOI are assumed to remain intact. In order to determine the amount of qualified coatings that fail, a 3 dimensional model of the containment to calculate the areas of specific surfaces (i.e. floors, walls, equipment, etc.) within the ZOI. Plant documentation identifying coating types and applications were then used to determine the associated volume, weight and density of coatings. The density and weight of each of the various qualified coatings is listed in Table 27.

Unqualified Coatings

Per NEI 04-07, all unqualified coatings inside and outside the ZOI are assumed to fail as a result of impingement and post-accident environmental conditions. The amount of unqualified coatings that will fail was determined in a similar manner. However, the weight of the applied coatings are determined based on a theoretical coating spread rates (sq. ft. per gallon @ 1 mil thickness) instead of specific vendor coating spread rates.

Based on Keeler and Long Report 06-0413, all unqualified epoxy topcoat system coatings outside of the ZOI are assumed to fail with the IOZ primer portion becoming particulates and the epoxy portion becoming chips. The size distribution of the paint chips was conservatively determined to be:

Size Range of Coating	Mass Percentage
1" – 2" (50% curled)	32.0%
1/2" – 1" (50% curled)	9.04%
1/4" – 1/2"	4.41%
1/8" – 1/4"	5.02%
<1/8"	49.5% as follows 37.1% - 15.6 mils (1/64" chips) and 12.4% - 6 mil chips
Total	100%

The density and weight of each of the various qualified coatings is listed in Table 28.

STP request for additional information (RAI) #26 is addressed by WCAP-16568-P.

Table 27 – Failed Qualified Coating Debris Source Term

Type of Coating	Density (lb/ft^3)	Weight (lb)
Epoxy	94	23
IOZ	457	553
Polyamide Primer	94	10

Table 28 - Failed Unqualified Coating Debris Source Term

Type of Coating	Debris Type	Density (lb/ft^3)	Weight (lb)
Epoxy (located in the Reactor Cavity)	chips	130-140	1,714
Epoxy (evenly distributed throughout containment)	chips	75-118	294
Alkyd	particulates	97-195	247
IOZ	particulates	97-256	843
Baked Enamel	particulates	82-187	268

Table 29 - Total Failed Qualified and Unqualified Coating Debris Source Term

Type of Coating	Debris Type	Density (lb/ft^3)	Weight (lb)
Epoxy	chips	75-140	2,008
Epoxy	particulates	94	23
Alkyd	particulates	97-195	247
IOZ	particulates	97-457	1,396
Baked Enamel	particulates	82-187	268
Polyamide Primer	particulates	94	10

Content Guide Item 3.h - Coatings Evaluation

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

Response

See section above.

Content Guide Item 3.h - Coatings Evaluation

• Describe any ongoing containment coating condition assessment program.

Response

STPNOC periodically conducts condition assessments of coatings inside containment. Coating condition assessments are conducted as part of the structures monitoring program. Visual inspection of coatings in containment is intended to characterize the condition of the coating systems. If localized areas of degraded coatings are identified, those areas are evaluated and scheduled for repair/replacement as necessary.

Content Guide Item 3.i Debris Source Term

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

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

  GL 2004-02 Requested Information Item 2(f) A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced into containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. Addressees may reference their responses to GL 98-04, "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*

Content Guide Item 3.i Debris Source Term

- *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.*

Response

During outages, STPNOC maintains containment cleanliness by adherence to the housekeeping procedure. Containment cleanliness is emphasized by the reactor containment building coordinators and the work supervisors. Prior to containment closeout at the end of the outage, the building coordinators oversee the cleanup of the containment work areas to achieve the goal of no loose debris.

Content Guide Item 3.i Debris Source Term

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

Response

STPNOC uses a procedure to maintain containment integrity with respect to potential sump debris sources. This procedure provides guidance for a visual inspection of the affected areas inside containment at the completion of each containment entry when containment integrity has been established to verify that no loose debris is present that could be transported to the emergency sump and cause restriction of pump suction during LOCA conditions.

STPNOC has a procedure that governs signs and labels that contains the requirements for labeling inside containment. These requirements are used to minimize potential sump debris items.

Content Guide Item 3.i Debris Source Term

- *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*

Response

Insulation replacement inside containment is either a like-for-like replacement as a maintenance activity ("rework") or is a modification with a design change that has been approved by STPNOC Engineering. The STPNOC design change process ensures that new insulation material that differs from the initial design is evaluated.

The STPNOC design change process also calls for evaluations of added metals such as aluminum that could contribute to post-LOCA chemical effects in the sump water. The process looks at coatings that are to be used inside containment. Impacts to post-LOCA recirculation flow paths and recirculation sump debris impact on internals of fluid containing components are part of the design change evaluation process described in the procedure.

Content Guide Item 3.i Debris Source Term

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

Response

Maintenance activities inside containment are subject to the cleanliness requirements that are given in the containment integrity surveillance procedure. The temporary change process also calls for an evaluation of items installed inside containment.

Content Guide Item 3.i Debris Source Term

- *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*

Response

STPNOC did not perform (and does not plan to perform) any insulation change outs or modifications to insulation banding or jacketing to reduce the potential insulation debris source term. No modifications to components or to systems were made to reduce the debris burden at the sump strainers.

Content Guide Item 3.i Debris Source Term

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

Response

The sump performance evaluation did not result in any changes to the containment coatings program.

Content Guide Item 3.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.*

Content Guide Item 3.j Screen Modification Package

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

Response

There is no change to the three independent sump pits. The sump screen above the pit has been removed; and now each sump has its own new strainer. There are no shared components between trains.

The new strainer assemblies for each of the 3 emergency sumps consist of two 5-module assemblies, one 4-module assembly, and one 6-module assembly. Each module is made up of eleven strainer disks. The strainer consists of stainless steel perforated plate with 0.095 in. diameter openings. Flow leaving the strainer assembly enters a four inlet plenum box (one inlet for each strainer assembly). The plenum box collects the flow from the strainer assemblies and directs it downward directly into the sump pit. An access cover is provided on the plenum box for internal inspection of the sump structures, vortex suppressor, and the strainer assemblies. The sump pit is now covered with a sump cover plate that prevents material from falling directly into the pit without passing through the strainer assemblies.

The new strainers have a surface area of 1,818.5 sq ft per sump. The old screens had a surface area of 155.4 sq ft per sump. For the design flow of 7,020 gpm per sump, the new strainers have a flow velocity of 0.009 ft/sec.

See the attached figures for the old screen design and the new strainer design.

Content Guide Item 3.j Screen Modification Package

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

Response

There are no high energy lines in the area of the emergency sumps except for the High Head Safety Injection lines which are used for accident mitigation and are not assumed to be the accident initiator. No piping reroutes were needed for installation of the new sump strainers. No component relocations or additions were necessitated by the new strainer installation.

Content Guide Item 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 Requested Information Item 2(d)(vii).

- *GL 2004-02 Requested Information Item 2(d)(vii) Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions*
- *Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.*
- *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.*

- *Summarize the evaluations performed for dynamic effects such as pipe whip, 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.*

Content Guide Item k. Sump Structural Analysis

- *Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.*

Response

The strainer components are designed in accordance with the AISC "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings, 7th Edition" with Supplement Numbers 1, 2 and 3; and SEI/ASCE 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members". The acceptance criteria are primarily in accordance with these codes. In circumstances where these specifications do not provide adequate guidance for a particular component, other codes, specifications or standards are used for guidance. For instance, the strainers are made from stainless steel materials. The AISC Specification does not specifically cover stainless steel materials. Therefore, ANSE/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities", is used to supplement the AISC Specification in any areas related specifically to the structural qualification of stainless steel. Note that only the allowable stresses are used from this Specification and load combinations and allowable stress factors for higher service levels are not used.

For the perforated plates, the equations from Appendix A, Article A-8000 of the ASME B&PV Code, Section III, 1998 Edition are used instead of the AISC code. A-8000 is deemed more appropriate because it is written specifically for perforated plates.

The strainer also has several components made from thin gage sheet steel, and cold formed stainless sheet steel. SEI/ASCE 8-02, "Specification of the Design of Cold-Formed Stainless Steel Structural Members", is used for certain components where rules specific to thin gage and cold form stainless steel are applicable. The rules for Allowable Stress Design (ASD) as specified in Appendix D of this specification are used. This is further supplemented by the AISC Specification where the ASCE

Specification is lacking specific guidance. Finally, guidance is also taken from AWS D1.6, "Structural Welding Code – Stainless Steel", as it relates to the qualification of stainless steel welds.

The new strainers are designed for loads due to weight, pressure, and dynamic loads. The dynamic loads come from seismic and from hydrodynamic drag loads due to sloshing. The strainers are loaded due to the inertia effect due to the motion of the containment floor during an earthquake. Hydrodynamic loads on the strainers are due to the motion of the water surrounding the strainer during a seismic event. Two weight loads are applicable. This includes the weight of the strainer components themselves and the weight of the debris that accumulates on the strainer. The design weight of the debris per strainer module is taken as 150 lbs. which bounds the calculated weight.

Thermal expansion loads are taken as zero because the strainers are essentially free standing structures that are basically free to expand without restraint due to sufficient gaps built-in to the pin connections that secure the modules to the floor tracks. Thermal expansion loads on the sump pit cover plate and the floor angles are considered negligible because these components have slotted holes or edge clips to allow for substantially unrestrained thermal growth.

The pressure load acting on the strainer is the differential pressure across the strainer perforated plates in the operating condition. This is defined as 5.71 ft. of head.

The load combinations and allowable stresses are based on the requirements of STP design criteria and are provided below.

Load Condition	Combination	Allowable
Normal Operating	DW + DP + WD	1.0 S
Normal Operating (Outage/Lift Load)	DW + LL	1.0 S
Operating Basis Earthquake	DW + DP + WD + OBE	1.0 S
Safe Shutdown Earthquake	DW + DP + WD + SSE	1.6 S

DW = Dead Weight Load
LL = Live Load (additional live loads acting on strainer assembly during outages only)
WD = Weight of Debris
DP = Differential Pressure
OBE = Operating Basis Earthquake
SSE = Safe Shutdown Earthquake
S = Required section strength based on elastic design methods and the allowable stress defined in the 7th edition AISC Specification, or other applicable specifications (ASCE 8-00, N-690, etc.)

Content Guide Item k. Sump Structural Analysis

- *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly*

Response

The calculation for seismic design margins for the strainers and their components shows that the stress Interaction Ratios (calculated stress/allowable stress) are less than one for both Operating Basis Earthquake and Safe Shutdown Earthquake loads.

Content Guide Item 3.k Sump Structural Analysis

- *Summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy line breaks (as applicable).*

Response

There are no high energy lines in the area of the emergency sumps except for the High Head Safety Injection lines which are used for accident mitigation and are not assumed to be the accident initiator. Thus no evaluations were needed for high energy line breaks.

Content Guide Item 3.k Sump Structural Analysis

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

Response

The new strainer design does not involve any backflushing.

Content Guide Item 3.l 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 <u>Requested Information</u> Item 2(d)(iv).

<u>GL 2004-02 Requested Information Item 2(d)(iv)</u>
The basis for concluding that the water inventory required to ensure adequate ECCS or CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths.

Summarize the evaluation of the 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.*

Content Guide Item 3.l Upstream Effects

- *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.*

Response

The Upstream Effects Evaluation provides a general description of the containment and sub-compartments as well as an examination of each elevation to identify physical and structural features that affect the flow of debris and water to lower containment. The Upstream Effects Evaluation preceded the Containment Water Level Calculation and served to identify potential flow path choke points and areas of containment where water volumes could potentially be held up from reaching the containment sumps due to the actual design layout or due to the added effects of debris resulting from high-energy line break accidents. The evaluation was based on a review of STP design documents including the UFSAR, calculations and containment drawings. No containment walkdowns were performed in support of the evaluation; however, containment photographs were reviewed. Plant personnel also provided additional information as needed.

Spray/break inventory and debris originating at upper elevations will eventually flow down to the 19'-0" elevation. The primary flow paths are through significant grated floor areas at upper elevations. See STP Response to Item 3.1 (4th bullet) below for additional information regarding the drainage flow path from the refueling cavity. Once at the 19'-0" elevation, significant concrete flooring routes the flow of water and debris to grated areas inside and outside the secondary shield wall. The primary sources of insulation debris are located above the 19'-0" elevation (e.g., the primary RCS piping and components). Therefore, the majority of insulation debris will be trapped at this elevation unless it can fit through standard floor grating. It is judged that this elevation will not become a choke point for flow because should large debris hold up at area of floor grating, the water has multiple other potential grated flow paths to the lower elevations. In addition, there is open communication between the areas inside and outside the secondary shield wall increasing the grated floor area available to pass flow.

The recirculation pool forms at the (-)11'-3" elevation. The ECCS emergency sumps are located in the southern quadrants of containment outside the secondary shield wall. The flow path around the outside of the secondary shield wall is generally open providing large flow passages to the ECCS emergency sumps. See STP Response to Item 3.1 (3rd bullet) for description of flow communication between areas inside and outside the secondary shield wall at the (-)11'-3" elevation.

Content Guide Item 3.l Upstream Effects

- *Summarize measures taken to mitigate potential choke points.*

Response

No measures are necessary to mitigate potential choke points.

Content Guide Item 3.l Upstream Effects

- *Summarize the evaluation of water holdup at installed curbs and/or debris interceptors.*

Response

There are only four (4) significant openings through which recirculation water and debris may pass from inside the secondary shield wall to the annular region outside the secondary shield wall at the (-)11'-3" elevation. These openings are four 30" circular vent holes located at a centerline elevation of (-)8'-6". Since these vent holes are above the floor, the secondary shield wall acts as a curb, or debris barrier, in the flow path to the containment sumps. As discussed in the response to Item 3.1 (2nd bullet), only small debris (small enough to fit through standard floor grating) is expected to reach the base floor elevation. Significant mounding of small debris is not expected to create a dam that would prevent flow through the vent openings. The volume of water below the vent holes is considered lost to the ECCS emergency sump.
No new curbs and/or debris interceptors have been installed.

Content Guide Item 3.l Upstream Effects

- *Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.*

Response

The refueling cavity drains via two (2) horizontal 6" drains with center line elevation located 10.75 inches above the bottom of the lower internals storage area. The two horizontal refueling cavity drains have an inside diameter of 6.065" and are straight pipe segments approximately 7 feet long. Alion Calculation ALION-CAL-STPEGS-2916-006, Rev. 0, "GSI 191 Containment Recirculation Sump Evaluation: Determination of Fibrous Debris Transport to the Refuel Cavity" and Westinghouse letter LTR-CSA-06-45 "Refueling Cavity Drain Lines" are the basis for concluding that the refueling cavity drain will not become plugged with debris. Based on debris generation and transport analyses, it was conservatively determined that 71 ft3 of fines (individual fibers) and 177 ft3 of small pieces (< 6") of fibrous insulation are transported to the Refueling Cavity. The STP analyses assume that the drains do not become blocked by debris, thus restricting flow from the cavity. No additional water hold-up are assumed for the refueling cavity except that volume required to induce flow through the cavity drains above the cavity floor.

Debris blown out of the steam generator compartments is expected to be distributed evenly around the operating floor (elevation 68'-0"). The refueling cavity drain lines are located on opposite walls of the lower internals storage area and large concentrations of debris would not be expected to land near both drain lines. There are no drain covers or trash racks for the drains that would allow fibers to build up and block flow. The largest debris transported to the refueling cavity (<6") is smaller than the drain line diameter (6.065"). In addition, fibrous debris is not rigid and will deform to fit through the drain if needed. The flow velocity through the drains has been determined to be greater than the incipient tumbling velocity for 6" pieces of Nukon; however, should debris accumulate in the drain line, the buildup of water behind the debris will provide sufficient driving force to push the debris through the straight pipes.

STP RAI #39 is addressed by this evaluation.

Content Guide Item 3.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 CSS in terms of potential wear of components and blockage of flow streams. Provide the information requested in GL 04-02 <u>Requested Information</u> Item 2(d)(v) and 2(d)(vi) regarding blockage, plugging, and wear at restrictions and close tolerance locations in the ECCS and CSS downstream of the sump.

<u>GL 2004-02 Requested Information Item 2(d)(v)</u>
The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the sump screen=s mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.

<u>GL 2004-02 Requested Information Item 2(d)(vi)</u>
Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

- *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.*

[1] *The draft NRC SE for this document was issued to the applicant in November 2007.*

Content Guide Item 3.m Downstream effects - Components and Systems

- *If NRC-approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE)*[1], *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.*

Response

Methods are discussed below under summary and conclusions. See next response.

Content Guide Item 3.m Downstream effects - Components and Systems

- *Provide a summary and conclusions of downstream evaluations.*

Response

The evaluations listed below were developed to address effects of debris carried downstream of the containment sump screen on the function of the ECCS and containment spray system (CSS) in terms of potential wear of components and blockage of flow streams. Close-tolerance subcomponents in pumps, valves and other ECCS and CSS components were evaluated for potential plugging or excessive wear due to extended post-accident operation with debris-laden fluids. The evaluations were developed in accordance with WCAP-16406-P-A, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191" Revision 1 and the accompanying NRC SER. No exceptions were taken to the WCAP-16406-P-A methodology.

STP RAI #31 is addressed by these evaluations.

The quantity of debris in the recirculating fluid that passes through the sump is characterized in terms of volume concentration. For downstream effects, this debris concentration is defined as the ratio of the solid volume of the debris in the pumped fluid to the total volume of water that is being recirculated by the ECC and CS systems. The resulting volume concentration from the initial debris concentration and total water volume is 0.0006188.

The mass of debris in the recirculating fluid that passes through the sump is characterized in terms of parts per million (ppm). For downstream effects, the total initial debris concentration comprised of the individual debris concentrations is defined as the ratio of the solid mass of the debris in the pumped fluid to the total mass of water that is being recirculated by the ECC and CS systems.

Debris Type	Concentration
Fibrous	5.6 ppm
Particulate	72.6 ppm
Coatings	744.0 ppm
Total	822 ppm

It was determined that all of the following ECCS and CSS components evaluated for STP can accommodate sump bypass particles without blockage: throttle valves; pipes, valves, and instrumentation; orifices and eductors; heat exchangers; and nozzles. A review of drawings and documents indicated that none of the ECCS and CS valves are throttled. There are no blockage/plugging issues: for existing piping, valves, and instrumentation lines; for the ECCS and CS flow element orifices, flow restricting orifices or in eductor passages; for RHR heat exchangers; and for the CS spray nozzles.

According to the criteria established in WCAP-16406-P-A, the wear impact on the valves identified in the STP evaluation was determined not critical and needs no further erosion evaluation.

Pump Wear Evaluation:

For pumps, the effect of debris ingestion through the sump screen were evaluated based on three aspects of operability, including hydraulic performance, mechanical shaft seal assembly performance, and mechanical performance (vibration) of the pumps. The pumps identified for evaluation were the High Head Safety Injection (HHSI), Low Head Safety Injection (LHSI), and Containment Spray (CS) pumps. According to the methodology established in WCAP-16406-P-A no effect on their hydraulic performance is expected.

For South Texas, the HHSI, LHSI, and CS pumps are multi-stage and must be evaluated for mechanical (vibration) performance. As evaluated in WCAP-16406-P-A, the abrasive, erosive, and Archard wear models are used to calculate the amount of wear (mils) on the suction and discharge sides of each stage of the multi-stage pumps.

The evaluation showed that the combined stiffness of the suction and discharge wear rings after being asymmetrically worn by free flowing abrasive wear and Archard wear, respectively, is less than the stiffness provided by both the suction and discharge wear rings being symmetrically worn to 2 times the design clearances for the HHSI, LHSI, and CS pumps. Therefore, the HHSI, LHSI, and CS pumps pass the mechanical (vibrations) evaluation

The mechanical shaft seal assembly performance evaluation resulted with the suggested replacement of the Low Head Safety Injection (LHSI), High Head Safety Injection (HHSI) and Containment Spray (CS) pumps' carbon/graphite packing assemblies with a more wear resistant material. However because South Texas Project has an Engineered Safety Feature (ESF) atmospheric filtration system for the building where the pumps are located, replacement of the carbon/graphite seal bushing is not required.

Heat Exchanger Wear Evaluation:

Tube failure for heat exchangers will occur when the resultant wall thickness after erosion is less than the required wall thickness to retain internal and external pressures. According to methodology established in WCAP-16406-P-A, the minimum wall thickness required to retain both internal and external pressures is less than the resultant wall thickness after erosion. Therefore, the heat exchangers are not expected to fail.

Heat Exchangers	D_0 (in)	Required t_m (in)	t_{actual} (in)	t_{eroded} (in)	Failure (yes/no)
RHR	0.75	0.0173	0.049	1.38E-4	no

Orifice Wear Evaluation:

If the orifice inside diameter due to erosive wear is changed by less than 3%, the system performance may be considered negligible. This criterion was established in WCAP-16406-P-A which states that an insignificant amount of wear occurs when they system flow through the orifice is changed by less than 3%. The STP evaluation considers the initial ratio of the diameters before erosive wear and the ratio of the diameters after erosive wear for single plate and multiple plate multiple hole orifices. It was found that the inside diameters of all the orifices change by less than 3% and therefore are not expected to fail.

Spray Nozzle Wear Evaluation:

Failure due to erosive wear for spray nozzles is expected to occur when the flow from the nozzle is increased by 10% due to the increase in the nozzle inner diameter. The STP evaluation considers the inner diameter before and after erosive wear begins. This acceptance criterion and methodology was established in WCAP-16406-P-A. It was found that the flow is changed by less than 2% which is less than the 10% limit; therefore the nozzles do not fail.

	Nozzle Velocity (ft/sec)	Accelerated Wear Rate (in/hr)	D_1 (in)	Flow Increase (%)
CSS Spray Headers	44.16	1.655E-6	0.3774	1.3

Instrumentation Blockage Evaluation:

The potential for blockage of the reactor vessel Level Instrumentation System (RVLIS) is not evaluated since South Texas Project has a Westinghouse design RVLIS, for which WCAP-16406-P states there is no blockage concern due to the debris ingested through the sump screen during recirculation.

Content Guide Item 3.m Downstream effects - Components and Systems

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

Response

No design or operational changes were made as a result of the current downstream evaluations.

Content Guide Item 3.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), 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.*

Because this document is still under NRC review, licensees should be aware of any NRC RAIs on it. The draft NRC SE for WCAP-16793 is expected to be issued in December 2007. After resolution of any open items from the staff's evaluation of this document, the staff will determine whether additional information is needed from licensees. Licensees should not delay their GL responses pending this information.

Content Guide Item 3.n Downstream Effects - Fuel and Vessel

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

Response

The following evaluations consider the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on core cooling, including fuel and vessel blockage. These evaluations were performed in accordance with WCAP-16406-P-A and WCAP-16793-NP," Evaluation of Long-Term Cooling Considering Particulate and Chemical Debris in the Recirculating Fluid" with no exceptions taken. The NRC SER is still pending on WCAP-16793-NP.

STP RAI #31 and 36 are addressed by these evaluations.

It was found that all evaluated dimensions of essential flow paths through the reactor internals are adequate to preclude plugging by sump debris. There is sufficient clearance for debris that may pass the containment sump screen since the limiting dimensions of the essential flow paths in the upper and lower internals are all greater than the maximum particle dimension. The maximum particle dimension is defined as twice the sump screen hole diameter. The sump screen hole diameter evaluated is 0.125 inches. The smallest clearance found in South Texas Project is 1.19 inches. Therefore, any screen size smaller than 0.59 inches will prevent plugging by sump debris in the vessel at South Texas Project. The new strainers have a hole size of 0.095 in. dia.

A fuel blockage assessment was performed for STP to demonstrate that blockage from fiber build-up will not compromise fuel cooling. The results of PCI prototype strainer performance testing based on water flow and debris mix conditions expected in South Texas containments following a postulated LOCA was used to determine the potential for STP fuel blockage. The evaluation used fibrous debris bypass test data from strainer testing in February 2008 to determine the fuel blockage potential. The analysis was performed in accordance with guidance from WCAP-16406-P, Revision 1 and WCAP-16793-NP (as modified by initial NRC staff comments on that document). The results of this evaluation indicate that the amount of fibrous debris generated by a large break LOCA will produce a fibrous debris build-up on the underside of the fuel bottom nozzle of 0.696 in. that exceeds the initial screening criterion of less than 0.125 inches. However, the conclusions of WCAP-16793-NP indicate that the formation of a fibrous debris bed on the under side of the fuel bottom nozzle will not cause sufficient blockage to prevent long term cooling.

No design or operational changes have been made as a result of the fuel blockage evaluation.

The in-vessel effects evaluation for STP was performed in accordance with guidance from WCAP-16793-NP as modified by conditions and limitations defined by the NRC staff in the draft safety evaluation.

The evaluation was performed by Westinghouse using the Loss of Cooling Accident Deposition Model (LOCADM) computer code to predict the growth of fuel cladding deposits and to determine the clad/oxide interface temperature that results from coolant impurities entering the core following a LOCA. The results are shown below. The cladding deposits and clad/oxide interface temperature do not challenge the acceptance criteria of total deposition thickness of <50 mils and maximum clad temperature of <800F. The "bump-up factor" methodology described in the PWROG letter (OG-07-534) was also used but had a negligible effect on both parameters.

Case	Scale Thickness microns	Total Deposition Thickness microns	Total Deposition Thickness mils	Max Clad Temperature Degrees F
Minimum sump volume	50.85	343	13.50	368.9
Maximum sump volume	34.24	326	12.84	368.9
Minimum sump volume with bump-up factor	54.35	346	13.64	368.9

Content Guide Item 3.o Chemical Effects[3]

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).*

[3] *The NRC staff expects to issue a draft SE on WCAP-16530, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," in November 2007.*

Response

The purpose of this analysis is to determine the type and quantity of chemical precipitates which may form post-LOCA. This input is intended to be used for screen performance testing and may be used in the evaluation of chemical effects on downstream equipment. The quantities of precipitates expected to form have been calculated, and were used for the sump strainer blockage headloss testing completed in 2008. The testing method and results are described in another section.

STPNOC evaluated the type and expected quantity of chemical products that would be expected to form in the recirculation fluid specifically for STP. Revision 0 of this evaluation used the chemical model/methodology developed in WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," prior to release of the accompanying NRC SER. No deviations were taken to the WCAP-16530-NP methods.

STP RAI numbers 6, 14 and 20 are addressed by the application of WCAP-16530-NP and the results from this evaluation. STP RAI numbers 2, 3, 4, 5 and 7 are addressed as material and condition inputs to the evaluation.

Input assumptions (and their basis) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects are described in the chemistry effects evaluation. The spray values from the time of recirculation were assumed to equal the sump pH values. This is conservative because the higher pH of the sump will produce more precipitates. The spray pH curve consists of the initial pH of 4.5 and the calculated values for the sump pH from the time of recirculation. Because the sump temperature data was only provided for 2 days, the final temperature was extended for the 30 day period. Extending the final temperature of 165 °F from 2 days to 30 days will provide more conservative values for precipitate formation since this temperature is higher than the actual temperatures expected due to cooling by the RHR heat exchangers.

Because of the uncertainty of the operator actions which may be taken post-LOCA, the evaluation was performed with spray continuing for both 24 hour and 30 day durations for both maximum and minimum recirculation volumes. This resulted in four sensitivity cases. The materials expected to contribute to the formation of chemical precipitates are: CalSil (Marinite) insulation, fiberglass insulation, microtherm, concrete, trisodium phosphate, submerged aluminum, and non-submerged aluminum. The resulting expected chemical precipitates are sodium aluminum silicate (NaAlSi308), aluminum oxyhydroxide (AlOOH), and calcium phosphate (Ca3(P04)2).
The case with the maximum recirculation water volume and 30-day spray duration yields the maximum total amount of precipitates.

	Maximum Recirculation Volume				Minimum Recirculation Volume			
Spray Duration	24 hours		30 days		24 hours		30 days	
	kg	ppm	kg	ppm	kg	ppm	kg	ppm
NaAlSi3O8	318.4	128.9	649.5	262.9	295.1	219.6	497.8	370.5
AlOOH	0.0	0.0	35.7	14.5	0.0	0.0	64.9	48.3
Ca3(PO4)2	162.7	65.9	162.7	65.9	132.0	98.2	132.0	98.2

Revision 1 of the STP chemistry effects evaluation used the refined methodology developed in WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model," to perform additional sensitivity cases. However, STP used the base case chemical effects quantities from Revision 0 during the performance of strainer head loss testing with chemical effects surrogates. For conservatism, the 30 day spray duration quantities were used for strainer testing.

Content Guide Item 3.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.

GL 2004-02 Requested Information Item 2(e) A general description of and planned schedule for any changes to the plant licensing bases resulting from any analysis or plant modifications made to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this GL. Any licensing actions or exemption requests needed to support changes to the plant licensing basis should be included.

Response

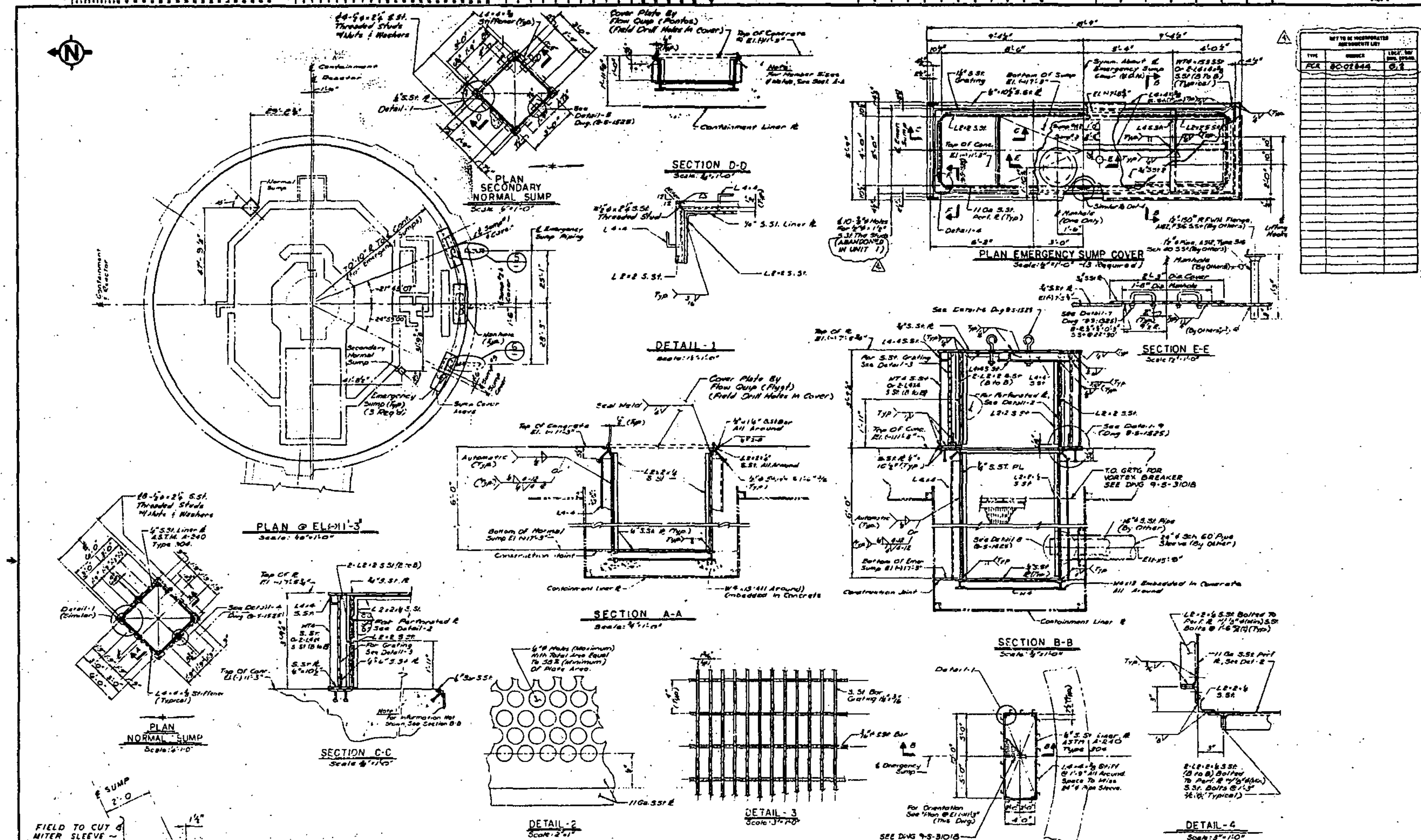
A license amendment request was submitted that proposed revising the Technical Specification (TS) Surveillance Requirement (SR) 4.5.2.d for the inspection of the Emergency Core Cooling System (ECCS) sumps for consistency with the new STP sump design.

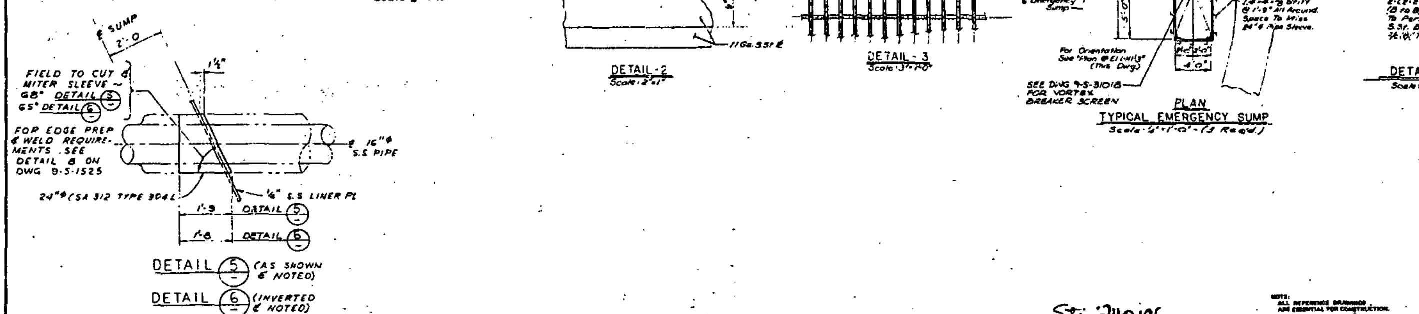
Attachments 1-5
Sump Design Drawings

1. 3C269S1516 Rev. 4 Original Sump Design
2. SFS-STP-DD-00 General Arrangement
3. SFS-STP-DD-02 Sump A
4. SFS-STP-DD-03 Sump B
5. SFS-STP-DD-04 Sump C

9-S-1516

9-S-1516





NOTES

1. FOR NOTES SEE DWG 9-S-1512.
2. DURING CONCRETE POUR, THE LINER & SHALL BE SHORED TEMPORARILY AT THE TOP TO RESTRAIN THE INWARD LINER MOVEMENT

REFERENCE DRAWINGS

9-S-1512 INTERNAL-S.ST. LINER @ EL.38'-6¼"
1-Z-0203 INSTRUMENT PIPING EL.(-)11'-8"
1-Z-0204 INSTRUMENT PIPING EL.(-)11'-8"
9-S-31018 EMERGENCY SUMP VORTEX BREAKER

THIS DWG SUPERSEDES BROWN & ROOT DWGS. 3C26-1-S-1516, REV. 8
3C26-2-S-1516, REV. 4

NOTE: ALL REFERENCE DRAWINGS ARE ESSENTIAL FOR CONSTRUCTION.

STI 240196

NO	REVISION	DFT	DATE
4	INC FCR DC-01999 ∮ NII AMEND LISTED	BAB	11-30-87
3	INCORP FCR EC-00376		02-10-86
2	INCORP FCR DC-00074E ADD REF FOR VORTEX BREAK		10-03-85
1	INCORP DCN 1		08/25/85
0	ISSUED FOR CONSTRUCTION	GAP	

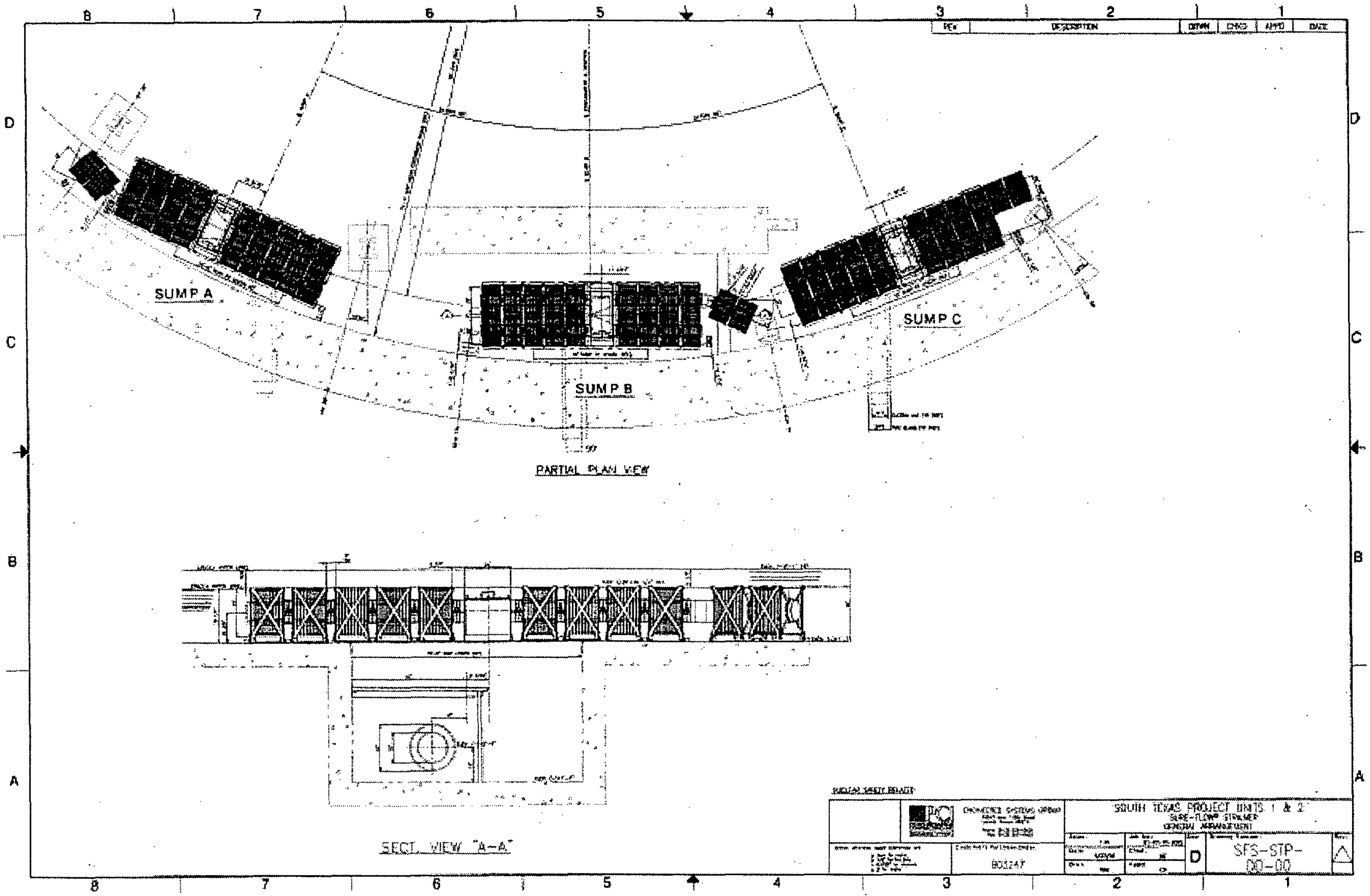
CHIEF ENGR 11/11/83

BECHTEL ENERGY CORPORATION
HOUSTON, TEXAS

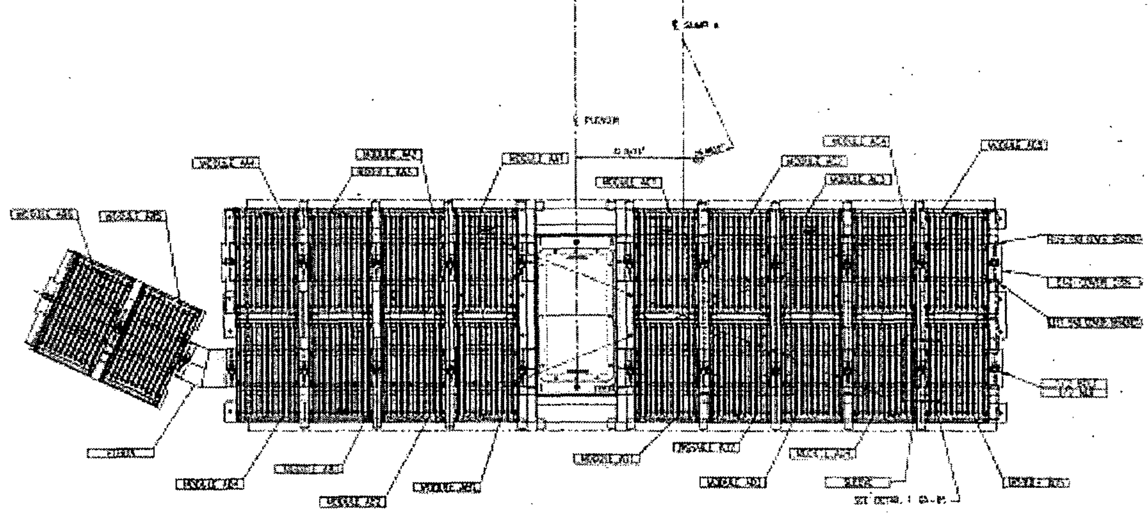
HOUSTON LIGHTING & POWER CO.
SOUTH TEXAS PROJECT

STRUCTURAL
REACTOR CONTAINMENT BUILDING
S. ST. LINER ℄ NORMAL & EMERGENCY SUMPS
UNIT NO 1 & 2

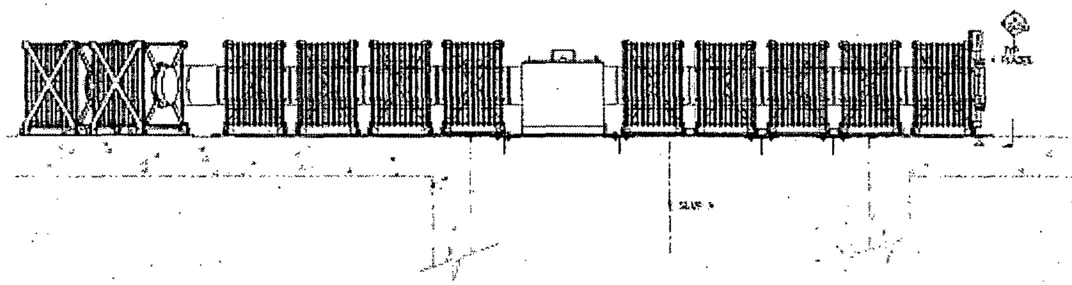
SCALE	JOB NO.	DRAWING NO.	REV.
AS NOTED	14926	3C26-9-S-1516	4



REV
DESCRIPTION
DRWN
CHKD
APPD
DATE
SUMP A
SUMP B
SUMP C
PARTIAL PLAN VIEW
SECT. VIEW "A-A"
SOUTH TEXAS PROJECT UNITS 1 & 2
D
SFS-STP-00-00



SUMP A PLAN



ELEVATION

NUCLEAR SAFETY RELATED

ENGINEERED SYSTEMS GROUP

SOUTH TEXAS PROJECT UNITS 1 & 2
SURE-FLOW® STRAINER
GENERAL ARRANGEMENT – SUMP "A"

Customer's Purchase Order: B03247

Size: D

Drawing Number: SFS-STP-00-02

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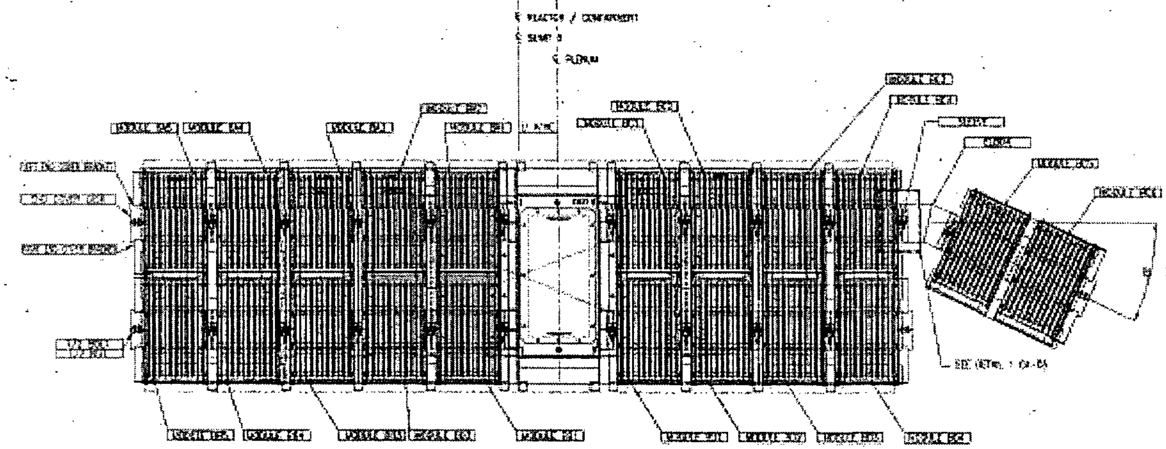
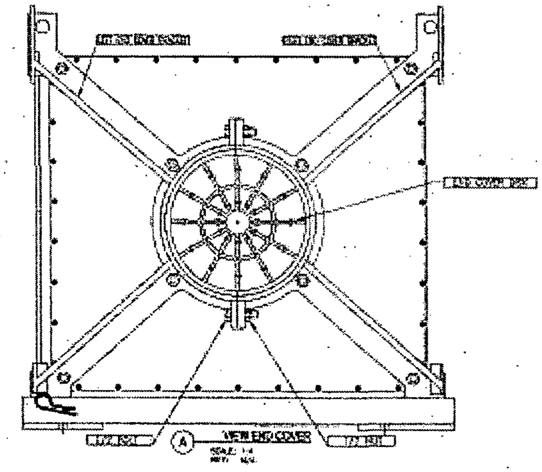
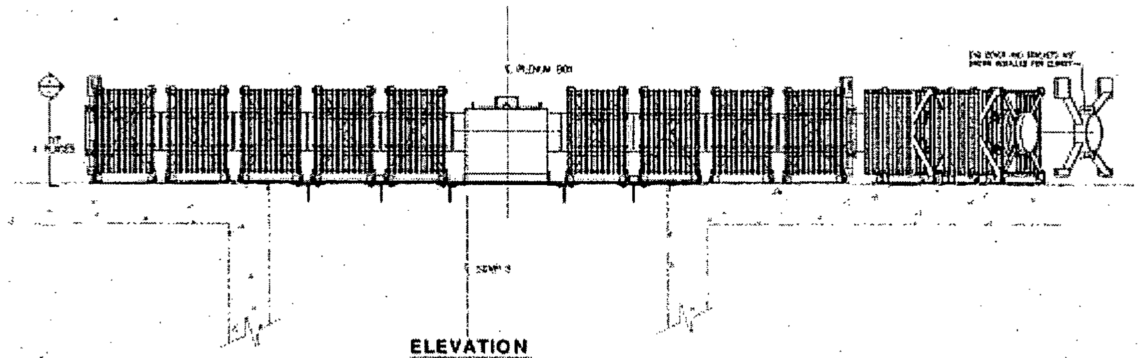


SUMP B PLAN





ELEVATION

NUCLEAR SAFETY RELATED

ENGINEERED SYSTEMS GROUP

SOUTH TEXAS PROJECT UNITS 1 & 2 SURE-FLOW™ STRAINER GENERAL ARRANGEMENT - SUMP B			
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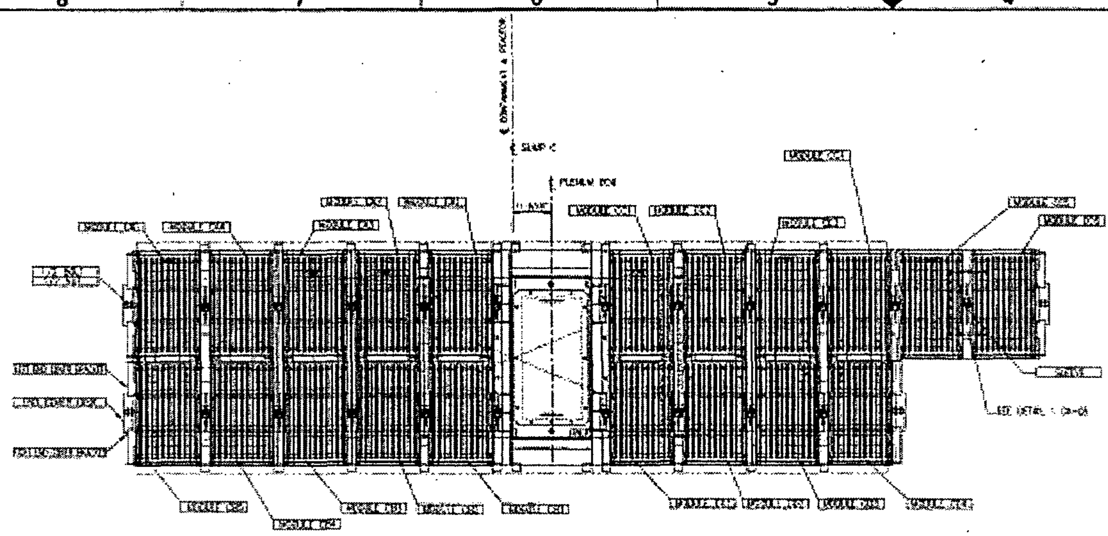
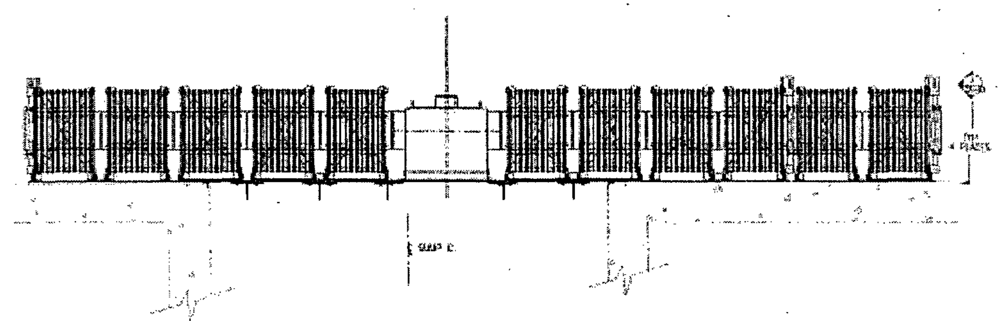
REV.	DESCRIPTION	DRWN	CHKD	APPD	DATE



SUMP C PLAN



ELEVATION

NUCLEAR SAFETY RELATED

ENGINEERED SYSTEMS GROUP

SOUTH TEXAS PROJECT UNITS 1 & 2
SURE-FLOW® STRAINER
GENERAL ARRANGEMENT – SUMP "C"

Size: D

Drawing Number: SFS-STP-DD-04

Customer Purchase Order: B01047