Comanche Peak Nuclear Power Plant

ENGINEERING REPORT

Generic Letter 2004-02 Supplemental Response

ER-ESP-001

REVISION 2

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Executive Summary

In response to Generic Letter 2004-02, Comanche Peak Nuclear Power Plant (CPNPP) has completed an analysis of the susceptibility of the ECCS and CSS recirculation functions for CPNPP Units 1 and 2. This work provides plant specific evaluations of debris generation, water and debris transport to the ECCS and CSS recirculation sump screens, the head loss associated with debris accumulation, and its associated effect on available net positive suction head. The structural capability of the sump strainers under debris loadings was also evaluated. The downstream effects of debris that passes through the screens on components in the ECCS flow path such as pumps, valves, orifices, spray nozzles, and core components were also evaluated.

Both Unit 1 and Unit 2 of CPNPP have installed new sump strainers to increase the available (i.e., submerged) screen area from the original approximately 200 ft^2 per sump to an area of approximately 4000 ft^2 per sump. Interrelated modifications which optimize emergency sump performance were also completed.

Analysis and testing were completed to ensure that the Emergency Core Cooling System (ECCS) and Containment Spray System (CSS) recirculation functions under debris loading conditions at CPNPP Units 1 and 2 were in full compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of Generic Letter 2004-02 [Ref. 1.A] on August 31, 2008.

Full compliance was achieved through analysis, testing, modifications to increase the available sump screen area, other changes to the plant to reduce the potential debris loading on the installed containment recirculation sump strainers, and programmatic and process changes to ensure continued compliance. The analysis methods being utilized for demonstrating this compliance are based on the methods described in NEI 04-07 as evaluated by the NRC in the Safety Evaluation Report for NEI 04-07.,

This report is complete with the exception of in vessel downstream effects and other followup activities related to GL 2004-02. To provide an acceptable method for addressing the potential for core inlet blockage by debris, the Pressurized-Water Reactor Owners Group (PWROG) developed Topical Report (TR) WCAP-16793-NP, Revision 1. The NRC staff has not issued a final SE on this WCAP. The completed analysis may require a revision depending on the final resolution of the issues. Therefore, the estimated completion date for the final in vessel analysis is 90 days following the final SE on the WCAP.

Section 1.0 Overall Compliance

1.1 Generic Letter 2004-02

In response to Generic Letter 2004-02 [Ref. 1.A], Comanche Peak Nuclear Power Plant (CPNPP) has performed an analysis of the susceptibility of the ECCS and CSS recirculation functions for CPNPP Units 1 and 2. This work provides plant specific evaluations of debris generation, water and debris transport to the ECCS and CSS recirculation sump screens, the head loss associated with debris accumulation, and its associated effect on available net positive suction head. The structural capability of the sump strainers under debris loadings was also evaluated. The downstream effects of debris that passes through the screens on components in the ECCS flow path such as pumps, valves, orifices, spray nozzles, and core components were also evaluated and are complete with the exception of in-vessel effects.

To provide an acceptable method for addressing the potential for core inlet blockage by debris, the Pressurized-Water Reactor Owners Group (PWROG) developed Topical Report (TR) WCAP-16793-NP, Revision 1, and submitted it to the NRC for review in June 2009. The NRC staff has not issued a final SE on this WCAP. The completed analysis may require a revision depending on the final resolution of the issues. Therefore, the estimated completion date for the final in-vessel analysis is April 2010.

For CPNPP, Luminant Power has implemented a holistic approach to resolve NRC Generic Safety Issue (GSI) 191. This approach includes:

- Design modifications to substantially increase the size and effectiveness of the containment emergency sump strainers. The new strainers have been qualified by prototypical testing for the design bases debris loading.

- Procedural actions to provide clear direction to the operations and technical support staff for monitoring post loss-of-coolant accident (LOCA) long term recirculation operation. These procedures include directions for monitoring system performance and contingency actions.

- Numerous conservatisms to ensure that the overall analyses and modification design includes substantial margins to account for uncertainties. CPNPP recognizes that uncertainties exist in various aspects of this issue and has taken adequate measures to accommodate these uncertainties.

Each aspect of the overall approach is described in more detail below and in the respective sections in 3.0.

The NRC has approved the methodology for meeting Generic Letter 2004-02 using the guidance of Nuclear Energy Institute (NEI) document titled *"Pressurized-Water Reactor (PWR) Sump Performance Methodology,"* dated May 28, 2004 as approved and supplemented by the NRC in an SER dated December 6, 2004. The sump performance methodology and the associated NRC SER have been issued collectively as NEI Report NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, dated December 2004. [REF. 4.A]

The guidance of Regulatory Guide 1.82, Revision 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident" [REF. 9.F] was also considered.

The methodology employs plant specific refinements as allowed by the NRC SE.

Additional data and methodology from ongoing research on specific issues such as downstream effects, chemical effects, and coatings were also used to the extent possible.

The methodology was supplemented with plant specific design and licensing basis information and contractor specific proprietary information and data as appropriate with the current state of knowledge.

The Current Licensing Basis for CPNPP, as well as plant-specific features, resulted in exceptions and/or interpretations being taken to the guidance given in RG 1.82 and NEI 04-07 as modified by the SE. Exceptions are described in the applicable section of this report. If any additional exceptions are identified during the completion of the in vessel analyses, they will be included in a future revision.

The testing and analyses provide the basis to show compliance with the applicable regulatory requirements including 10 CFR 50.46, and 10 CFR 50 Appendix A, General Design Criteria 35 and 38.

The 90 day response to Generic letter 2004-02 was provided March 7, 2005 [Ref. 2.D]. Updates were provided March 31, 2006 [Ref. 2.E] and December 31, 2006 [Ref. 2.Q].

The original schedule for completion of GSI-191 was December 31, 2007. Due to delays in completing analysis and testing, an extension to June 2008 was requested [Ref. 2.N] and granted

[Ref. 1.B]. The first supplemental response to GL 2004-02 was provided February 29, 2008 [ref. 2.O] in accordance with NRC authorization of all PWR licensees up to two months beyond December 31, 2007 (i.e., to February 29, 2008), to provide the supplemental responses to the NRC [Ref. 1.D]. A status was provided in June 2008 [Ref. 2.P] along with a request for an extension for completion of test reports and subsequent analysis to August 31, 2008. The supplemental response was revised and submitted November 26, 2008 [Ref. 2.T]. This is the second revision of the supplemental report to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors".

It is Luminant's intent to complete the final supplemental report approximately 90 days after the NRC SE on WCAP-16793-NP, Revision 1.

1.2 Holistic Case

Because of the unknowns with respect to chemical effects and lack of clear guidance or acceptance criteria for downstream effects when Generic Letter 2004-02 was issued, the Comanche Peak approach to GSI-191 has been to design for success. Design modifications were made to install state of the art sump debris strainers and to optimize their performance.

Next, to be sure that the design was adequate, an extensive calculation and testing process was followed consistent with evolving industry knowledge and NRC expectations.

Each phase of the calculation process, while interdependent, involves its own set of phenomena and uncertainties. Known limitations in the knowledge base of these phenomena and associated calculation methods are typically accounted for in a bounding fashion during each phase of the process. The combined effect of these bounding calculations is a pessimistic prediction of ECCS recirculation performance that, while conservative, provides little insight into the realistically expected performance during a design basis event. The expected behavior in each phase of a prototypical event is significantly less severe than assumed for the analysis and testing.

In general, this report does not address or credit expected behavior. Only two are discussed. The effect of containment air partial pressure to provide significant NPSH margin once sump temperature decreases is noted in Section 3.g. This margin would be available before chemical precipitates formed. The effect of prototypical LOCA temperatures on the transport of fibers is noted in several sections. Neither of these were credited to meet acceptance criteria. However, they represent a significant level of margin in already conservative and bounding analysis.

Each section of this report that describes the analysis and testing notes conservatisms that bound uncertainties and assure design margins for the future. These conservatisms are summarized for each section below.

3.a Break Selection

The LOCA break selection methodology for Comanche Peak results in identifying the worst debris generation break for each type of debris rather than some combination of debris.

The LOCA break selection was performed to bound both units for each debris source.

The break selection methodology for Large breaks with two or more different types of debris, when applied to secondary line breaks, results in debris generation beyond the design and licensing basis.

3.b Debris Generation/Zone of Influence (ZOI) (excluding coatings)

No credit for shadowing by platforms, grating, supports, or other equipment was taken.

Because the damage pressure for Transco RMI is conservative and the CPNPP Min-K encapsulation is significantly more robust than the tested Transco RMI, use of the damage pressure assigned Transco RMI is a significant conservatism.

No credit was taken for the Comanche Peak configuration for lead shielding blankets with multiple layers, stainless steel banding, and rounded profile to reduce debris generation. The conservatively calculated debris was also used in the calculation of chemical precipitates (Section 3.o). This is a significant conservatism.

The damage pressure for unjacketed Min-K and Diamond Power Mirror® insulation with standard bands in the URG is 4 psi. The damage pressure for unjacketed NUKON in the URG is 10 psi. HEMYC fire blankets would be close to unjacketed NUKON in material and construction. Therefore, assuming the lower destruction pressure is very conservative.

When calculating blockage, paper labels were assumed to not curl or degrade even though this phenomenon was observed in testing (Section 3.f.3.3). Paper tags are less than 22% of the total unacceptable labels and represent an insignificant amount of fiber. Assuming blockage of sacrificial surface area is more conservative than testing paper labels. Paper labels are likely to settle before reaching the strainer in prototypical conditions.

3.c Debris Characteristics

100% transport of Min-K fines was assumed.

3.d Latent Debris

The 15% fiber assumption for latent debris by weight results in a significant conservatism in the quantity and characteristics of latent fiber.

3.e Debris Transport

Although some of the debris washed down in the RCS loop bays would have to pass through two levels of grating to reach the floor, this was conservatively neglected in the analysis. only one level of grating was credited for debris retention.

One of the significant conservatisms in the Comanche Peak debris transport analysis is the assumption that all debris in upper containment would be washed down to the pool with the exception of a portion of small piece debris held up on grating (i.e. all debris is washed to the various grated hatches and openings without being held up on the concrete floors).

Another significant conservatism in the Comanche Peak debris transport analysis is assuming that all debris that is not blown to upper containment would be washed back to the recirculation pool. As discussed in Appendix VI of the SE, approximately 17% of fiberglass fines and small pieces would be captured when the flow makes a 90-degree bend [Ref. 4.A, Volume 2]. Additional debris would also be captured by miscellaneous structures and grating. In the Comanche Peak debris transport analysis, approximately 10% of small fiberglass debris was determined to be captured on walls and miscellaneous structures in the steam generator compartments (see Section 5.4 of the debris transport calculation). Although fiberglass fines would be captured similar to the small pieces, no credit was taken for this capture and all of the small pieces not blown to upper containment were conservatively assumed to be washed back to the containment pool.

Since most of the walls and structures in the steam generator compartments are shielded from the containment sprays, the majority of the debris captured on the walls and structures would be retained. Taking credit for this would reduce the overall transport fraction for fiberglass fines by approximately 10% (equivalent to the capture for small fiberglass), as well as a partial reduction in the transport for the small pieces of fiberglass. For the limiting fiberglass debris generation case, the reduction in fiberglass fines transport would result in a reduction of approximately 1 ft^3 at the strainers (42 ft^3 x 17% fines x 10% capture).

Although it was not credited, the presence of RMI and other less transportable debris in the recirculation pool would tend to trap more readily transportable debris during pool fill reducing the overall recirculation transport.

No settling of latent debris in the recirculation pool was credited. Although a much larger fraction of debris would likely be washed to the inactive reactor cavity during pool fill, the transport fraction was conservatively limited to 15% of that not blown into the upper containment in accordance with the SE.

Prototype testing was done with an ultra-conservative test temperature below 50 degrees F. Fiberglass fibers settle in 20 to 60 minutes in 50 °F water versus 20 to 30 seconds in 120 °F water [Ref. 9.Q, NUREG/CR-2982, "...water temperature has a paramount effect on buoyancy..."]. Tests conducted at 128 °F and 169 °F confirmed the effect on settling of fiberglass [Ref. 15.A, Test Report No. ITR-92-03N]. This is a significant conservatism in the prototype test because the fine fibrous debris is mixed at and around the test module at the beginning of flow and the suspended fibers did not settle as they would in a prototypical event.

3.f Head Loss and Vortexing

Conservatisms were identified in the generic chemical model which could be addressed through the inclusion of more plant-specific inputs. However, the refinements in WCAP-16785-NP Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model [Ref. 6.C] were not used.

Although Sodium Aluminum Silicate (NaAlSi3O8) makes up 83% of the precipitate, Aluminum Oxyhydroxide (AlOOH), which causes higher head losses, was used as the surrogate for testing.

Fiber debris preparation resulted in smalls used in Comanche Peak testing being comprised of up to 41% fines.

Large Fiber Debris is defined by PCI as fibrous debris that WILL NOT pass through a 1" x 4" opening in a dry form. Per NEI 04-07, the opening size through which fibrous debris classified as "large" fibers do not pass is 4" x 4". Therefore, PCI is using a much more conservative criteria for the 'large' fiber classification. Large fibrous debris is processed using a "wood chipper". The capture method of collecting not only 'large' fibrous debris clumps but also the 'small/fine' fibrous debris discharged by the wood chipper results in some percentage of fines being included in the large debris.

Intact blankets were prepared as Large Fiber debris for the Comanche Peak testing.

The transport over the debris interceptor was 0.18 fps in the head loss test flume as opposed to 0.12 fps in the plant.

The conservative debris preparation resulted in both large and intact fiberglass pieces closer to smalls than to large fiberglass pieces as defined.

The transport over the debris interceptor was 0.18 fps in the head loss test flume as opposed to 0.12 fps in the plant.

3.g Net Positive Suction Head (NPSH)

The floor drain system and the hydrogen mixing vents in all of the intermediate slab elevations in the containment are assumed not to provide a drainage path for water held up on these slabs. The only drainage from these slabs is assumed to be through opening in the slab perimeter. Analysis performed for other reasons has shown that the hydrogen mixing vents provide a substantial drainage path through each slab, and due to their number and widespread locations they will not all be clogged with debris regardless of the accident or its location. However, no credit was taken for these paths.

The clean strainer NPSHa margins are based on the minimum flood levels specified in the Sump Strainer Specification. Actual margins are slightly higher as the elevations in the Strainer Specification are more conservative (lower) than the minimum flood levels determined. In addition, the minimum flood levels are determined at the point of initiation of recirculation with maximum holdup of steam and water above the sump pool. The flood level will increase with time as the containment cools and the sprays are terminated.

The calculation of NPSH margin at the minimum flood level corresponding to the initiation of recirculation with the debris loaded head loss after 30 days of recirculation is a significant conservatism.

3.h Coatings Evaluation

All unqualified coatings are assumed to fail. Note that "unqualified" coatings are all actually "indeterminate" coatings. As shown in various tests (e.g. EPRI OEM Coatings tests), they may or may not fail completely during a design basis accident. They are conservatively assumed to fail if classified as Unqualified. This is a significant conservatism in the evaluation of emergency sump performance.

Acceptable steel coatings in the Zone of Influence between 4D and 10D are conservatively included in the debris. DBA-unqualified steel coatings in the 10D ZOI are double counted in the debris.

The assumed quantity of debris from original equipment manufacturer unqualified coatings is very conservative. Industry testing shows many coatings with failures only in the 20% to 50% range.

3.j Screen Modification Package

The structural requirements specified for the new strainers required design for a differential pressure of 14 feet of water (see Section 3.k.1) to account for the maximum flood level and NPSH margin available.

3.l Upstream Effects

No credit was taken for the intervening Fuel Handling Bridge Crane or Refueling Machine over the upender area to reduce the debris load on the drain stainers.

No credit for the drain strainers were taken to reduce sump debris loads.

3.m Downstream effects - Components and Systems

Transport testing showed that no small RMI pieces would each the strainer. However, no credit was taken in the debris ingestion analysis.

Bypass testing and analysis showed that no coatings chips 1/64 inch and larger would bypass the strainer. However, no credit was taken in the debris ingestion analysis.

The 6 mil chip debris bypass was shown to deplete with time; however, credit for decay was not taken in the analysis except for the SI Pumps.

3.o Chemical Effects

No credit for solubility or the increased NPSH margin at the lower temperature were taken.

Although Sodium Aluminum Silicate (NaAlSi3O8) makes up 83% of the precipitate, Aluminum Oxyhydroxide (AlOOH), which causes higher head losses, was used as the surrogate for testing. See Section 3.f, above.

Section 2.0 General Description of and Schedule for Corrective Action

2.1 General Description

Comanche Peak Nuclear Power Plant (CPNPP) is a two unit station: each unit is a 4-loop Westinghouse PWR. The reactor buildings are large dry, highly compartmentalized containment buildings. Reflective metallic insulation is used for all thermal (hot) applications except in limited cases where high efficiency insulation is required. Low density fiberglass insulation is used for anti-sweat (cold) applications. CPNPP is classified as a low fiber plant.

Activities are complete that ensure that the Emergency Core Cooling System (ECCS) and Containment Spray System (CSS) recirculation functions under debris loading conditions at CPNPP Units 1 and 2 are in full compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of Generic Letter 2004-02 [Ref. 1.A].

NRC regulations in Title 10, of the Code of Federal Regulations Section 50.46, 10 CFR 50.46 [Ref. 9.A], require that the ECCS have the capability to provide long-term cooling of the reactor core following a LOCA. That is, the ECCS must be able to remove decay heat, so that the core temperature is maintained at an acceptably low value for the extended period of time required by the long-lived radioactivity remaining in the core. GDC 35 is listed in 10 CFR 50.46(d) and specifies additional ECCS requirements.

Although not traditionally considered as a component of the 10 CFR 50.46 ECCS evaluation model, the calculation of sump performance is necessary to determine if the sump and the ECCS are predicted to provide enough flow to ensure long-term cooling.

Similarly, Appendix A to 10 CFR Part 50 [Ref. 9.D], GDC 38 provides requirements for containment heat removal systems for LOCA, and GDC 41 provides requirements for containment atmosphere cleanup for LOCA. Comanche Peak Nuclear Power Plant credits the Containment Spray System (CSS), at least in part, with performing the safety functions to satisfy these requirements. In addition, CPNPP credits CSS with reducing the accident source term to meet the limits of 10 CFR Part 100 [Ref. 9.E] for LOCAs.

RAI 37 The mitigation of secondary line breaks, postulated in accordance with GDC 4, is not subject to 10CFR50.46, GDC 35, GDC 38 or GDC 41. Containment Spray is not required to meet the limits of 10CFR100 for secondary line breaks. Therefore, secondary line breaks were not covered by the backfit analysis in Generic Letter 2004-02.

Although the regulations identified in GL 2004-02 are not applicable to secondary line breaks, the CSS could be automatically actuated in the event of a secondary line break such as a Main Steam Line Break. Therefore, as requested by the Generic Letter, CPNPP has included an evaluation of the effect of secondary line breaks on CSS recirculation sump performance.

NOTE: The ECCS is not required for secondary line breaks.

The activities to assure compliance with the applicable regulatory requirements, above, were complete on August 31, 2008 in accordance with REF. 1.J.

Full compliance was achieved through analysis, testing, modifications to increase the available sump screen area, other changes to the plant to reduce the potential debris loading on the installed containment recirculation sump strainers, and programmatic and process changes to ensure continued compliance. The analysis methods utilized for demonstrating this compliance are based on the methods described in NEI 04-07 as evaluated by the NRC in the Safety Evaluation Report for NEI 04-07 [Ref. 4.A]. Further information regarding this approach is provided in subsequent sections of this report.

2.1.1 Modifications

Both Unit 1 and Unit 2 of CPNPP have installed new sump strainers to increase the available (i.e., submerged) screen area from the original approximately 200 ft^2 per sump to an area of approximately 4000 ft^2 per sump. The previous sump screens were 75 inches tall (partially submerged) whereas the new strainers are approximately 45 inches tall (fully submerged). In support of the new strainer design, Refueling Water Storage Tank (RWST) switchover setpoints were revised to ensure the new strainers are fully submerged at the completion of switchover from RWST injection to sump recirculation. The replacement strainer size was based on the best available knowledge at the time for the proposed installation areas, potential debris generation and transport, and potential head loss across the screen. The new strainers were installed in the existing locations within containment. The strainers were installed inside the structure of the previous screens located outside the secondary shield walls, isolated from the dynamic effects of a LOCA or secondary line break.

In additional to the strainer modification, other interrelated modifications have been completed. These include:

Revised RWST switchover setpoints and motor operated valve modification

Installation of debris screens and strainers for drains in the refueling cavity

Drain holes added to the reactor vessel head stand shield wall

Modifications to minimize water holdup on floors and miscellaneous items

Installation of debris interceptors

Installation of water control features to optimize sump performance

ECCS and CSS pump suction pressure monitoring instrumentation upgrades to meet Regulatory Guide 1.97, Revision 2.

RAI 37 Defense in Depth: Suction pressure monitoring instrumentation was added to the Containment Spray System during the GSI-191 modifications. This instrumentation gives a direct indication of the adequacy of the pump NPSH. In the event of indication of low NPSH, procedures would direct the operator to stop the affected pumps. Stopping the spray pumps for a short period of time would be insignificant to containment cooldown. Stopping suction pumps have shown a tendency to cause some of the debris bed on strainers to sluff off.

2.1.2 Qualification of the Strainer System

To establish the qualification of the new strainer system, numerous additional activities have been completed. These activities have been performed, except where noted herein, pursuant to the guidance given in NEI 04-07 Volume 1, Pressurized Water Reactor Sump Performance Evaluation Methodology (GR), and NEI 04-07 Volume 2, Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Revision 0, December 6, 2004 (SE). [Ref. 4.A] These activities are:

- Containment Condition Assessments – A series of walkdowns have been completed. Containment walk downs were completed for CPNPP Unit 1 during the Spring 2004, 1RF10 outage. Containment walk downs for CPNPP Unit 2 were completed during the Spring 2005, 2RF08 outage. The walk downs were performed using guidance provided in NEI 02-01, "Condition Assessment Guidelines, Debris Sources inside Containment," Revision 1 [Ref. 5]. In addition, the Unit 2 walkdown included extensive sampling for latent debris (dust and lint) considering guidance in NEI 04-07 Volume 2 (i.e., the NRC SER). Supplementary walkdowns to assess containment conditions were performed. See Section 3.d for details.

- Replacement of Radiation Protection Locked High Radiation Doors to the Steam Generator Compartments – These doors, consisting of wire mesh, were replaced with doors with bars with six inch wide openings. This was done to prevent upstream blockage and hold up of water and debris during the blow down and wash down phase of LOCA. Delayed release of debris after the inactive sump fills is considered adverse to emergency sump performance. This will optimize the transport of debris to the inactive sump under the reactor vessel as well as low flow areas of the containment floor. See Section 3.j for additional details.

- Redesign of the Drain Path to the Inactive Sump – The locked high radiation door to the incore instrumentation guide tube room, consisting of wire mesh, was replaced with a door with bars with six inch wide openings. The floor hole personnel safety barrier around the guide tubes was redesigned to be raised with vertical bars with six inch openings. This was done to prevent blockage and hold up of water and debris during the blow down and wash down phase of LOCA. The path to the inactive sump is at Elevation 808'-0" whereas there is an effective curb around the emergency sumps that is at elevation 808'-3-7/8". During sump pool fill, flow and debris will be preferentially directed to the inactive sump. This will optimize the transport of debris to the inactive sump under the reactor vessel as well as low flow areas of the containment floor. See Section 3.e for additional details.

- Removal of Radiation Protection Barriers and a Tool Room Enclosure – Cages consisting of wire mesh which are no longer required were removed. This will prevent blockage by debris which could affect flow to the emergency sumps. See Section 3.j for additional details.

- Implementation of Compensatory Actions – Compensatory actions in response to NRC Bulletin 2003-01 have been implemented as permanent changes in procedures [Ref. 8.D]. The modifications to the locked high radiation doors described above were also completed as compensatory actions. These improved doors will be retained pursuant to

GL 2004-02. [Also see Ref. 2.H and Ref. 2.I]

RAI 37 Defense in Depth: The compensatory actions in response to IE Bulletin 2003-01 were made permanent. This action is to start refill of the Refueling Water Storage Tank (RWST) so that additional water can be added to containment to increase water level and NPSH margin. Alternatively, the refilled water in the RWST could be used to back flush the strainer via the ECCS System. The discharge of one RHR pump can be cross tied to the discharge of the other RHR pump. By use of that pump's mini-flow bypass line, the running pump's discharge can be directed to the suction side of the non-running pump and to the emergency sump. Although this is not a credited design basis function, it significantly reduces the significance of potential strainer blockage due to a secondary line break.

- Containment Coatings Assessments – The previous Licensing Basis for CPNPP coatings in the containment, as approved by the NRC, was that 100% failure is acceptable for sump performance. A reassessment of CPNPP containment building protective coatings was conducted in support of the response to GL 2004-02. See Section 3.h for additional details.

- Evaluation of the Plant Labeling Program – The plant labeling program was evaluated to determine suitable material and program changes in support of the response to GL 2004-02. [Ref. 8.F] See Section 3.i for additional details.

- Upstream Effects Evaluation – The upstream effects evaluation [REF. 7.C.1] is complete. As part of the review performed for resolution of GL 2004-02, a potential plugging point was identified. This potential plugging point is the refueling cavity drains. These drains return a portion of the upper containment spray flow back to the lower volume of containment to support the water level analysis. CPNPP installed debris screens and strainers over the drains to prevent blockage of the drain paths in both units. Additional water holdup volumes were identified, and modifications were made. See Section 3.j for details.

- Event Characterization – The event characterization [REF. 7.A.1] evaluates the licensing and design basis to establish the design basis events which require emergency sump recirculation. Additionally, based on plant design inputs, the event characterization establishes the sump flow rates, recirculation pool water level and recirculation pump minimum Net Positive Suction Head margins.

- Debris Generation Evaluation – Bounding (Unit 1 and Unit 2) debris generation analyses [REF. 7.A.2] were performed in support of analysis for the new design. Refinements for the new plant design and configuration are included in the revision.

- Debris Transport Evaluation – Bounding (Unit 1 and Unit 2) debris transport analyses [REF. 7.A.3] were performed in support of refined analysis for the new design. Computational Fluid Dynamics (CFD) analyses were used as input to design modifications to optimize sump performance. This report was revised based on the completed modifications to the plant design.

- Debris Load Evaluation – Bounding (Unit 1 and Unit 2) debris analyses [REF. 7.A.5] were performed in support of the analysis and testing for the new design. This report is complete based on the completed modifications to the plant design.

- Downstream Effects Evaluations – In accordance with NEI 04-07, the ECCS and CSS are evaluated for blockage and wear concerns. The following evaluations were performed:

  Blockage (except for reactor vessel)

  Equipment Wear

  Valve Wear

  Reactor Vessel Blockage

  Fuel Blockage

  Evaluation of Long Term Cooling*

  * The NRC staff has accepted WCAP-16793-NP, Revision 1 for review, but has not issued a final SE on this WCAP. The CPNPP analysis and licensing basis are in accordance with WCAP-16793-NP Revision 1. When the NRC SE on WCAP-16793-NP is issued, it will be reviewed for impact and the evaluation of long term cooling will be revised as appropriate.

- Calculation of Required and Available NPSH – The available NPSH margin has been calculated in support of strainer modifications performed for resolution of this issue. These analyses were revised to determine the headloss across the clean strainer. The head loss margins were validated by testing which demonstrated the margins in the new strainer design. See Section 3.f for details.

In order to increase design margins, actions were completed to remove unqualified labels, tags, and tape from containment to the extent practical (see Section 3.b for details). Modifications were made to reduce the inventory of aluminum (see Section 3.o for details).

2.1.3 Potential or Planned Design/Operational/Procedural Changes

CPNPP performed evaluations of existing engineering design specifications, engineering design standards, engineering programs, modification and maintenance processes and procedures, and station operation processes and procedures. Potential changes were identified. These changes will ensure the inputs and assumptions that support the current analysis effort are incorporated into the applicable documents to maintain the necessary attributes for future compliance with these requirements.

Completed changes include:

Revision to design control procedures to explicitly address emergency sump performance impacts

Revision to Design Basis Documents and Engineering Specifications to ensure necessary control of existing and future materials that could affect sump performance

Revision to the Coatings Program

Revision to the Station Labeling Program to ensure control of label materials and locations in containment

Enhancements to other procedures are continuing under Reference 3.J.

2.2 Schedule

Luminant Generation Company LLC (Luminant Power) completed all corrective actions required in support of resolution of Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02 prior to August 28, 2008 [Ref. 2.U]. The only open corrective action activity at that time was the Downstream Effects Evaluations, Fuel. This action is constrained by WCAP-16793, Revision 1 [Ref. 6.F] which is still under NRC review.

	Corrective Action Description	Status	Ref.
1.	Containment condition assessment	Complete	3.A
2.	Replacement of Radiation Protection Locked High Rad Doors to the Steam Generator Compartments	Complete	3.B
3.	Redesign of the Drain Path to the Inactive Sump	Complete	3.B
4.	Removal of Radiation Protection Barriers and a Tool Room enclosure	Complete	3.C
5.	Implementation of Compensatory Actions	Complete	3.D
6.	Reassessment of Containment Coatings to provide current assessment of unqualified coatings.	Complete	3.E
7.	Evaluation of the Plant Labeling Program	Complete	3.F
8.	Upstream Effects Evaluation	Complete	7.F.2
9.	Event Characterization	Complete	7.F.10
10.	Debris Generation Evaluation (including Confirmation that Debris Generation bounds Units 1 and 2)	Complete	7.F.7
	Testing to support the selection of a 4D ZOI for qualified coatings destruction pressure.	Complete	7.E.6
	Testing to determine unqualified coating debris source terms	Complete	3.E
	As-built configuration of Radiant Energy Shields	Complete	7.F.42
	Confirmation that vapor barrier materials were not used in the fiberglass insulation applications	Complete	7.F.15
	Identification of flexible tubing material used for RCP lube oil collection system	Complete	7.F.43
	Revision of analysis for the above and minor open items	Complete	7.F.7
11.	Debris Transport Evaluation (including Refinements based on new sump strainers and related design modifications)	Complete	7.F.8
12.	Summary of Debris Generation and Transport Evaluation	Complete	7.F.9
13.	Downstream Effects Evaluation, Blockage	Complete	7.F.3
	Determination of RHR Pump Seal Cooler Tube ID	Complete	7.F.44
14.	Downstream Effects Evaluation, Equipment Wear	Complete	7.F.4
15.	Downstream Effects Evaluation, Valve Wear	Complete	7.F.4
16.	Downstream Effects Evaluation, Reactor Vessel	Complete	7.F.5
17.	Downstream Effects Evaluations, Fuel	In process	
18.	Downstream Effects Evaluation, Long Term Cooling	Complete	7.F.23
19.	Calculation of Required and Available NPSH	Complete	3.H

	Corrective Action Description	Status	Ref.
	Chemical effects testing.	Complete	3.H
	Head loss and bypass testing on the replacement strainer utilizing the results of the site-specific debris generation and debris transportation evaluations.	Complete	3.H
20.	Strainer Replacements (and interrelated modifications)	Complete	3.H
	Pump suction pressure instrumentation	Complete	3.H
21.	Strainer Structural Analysis	Complete	3.H
22.	Potential or Planned Design/Operational/Procedural Changes		
	Revision to design control procedures	Complete	3.A
	Revision to Design Basis Documents and engineering specifications	Complete	3.A
	Revision to the Coatings Program	Complete	3.E
	Revision to the Station Labeling Program	Complete	3.F

Other related close-out activities and open corrective action documents include:

Enhancements to the procedures and programs to further assure control of potential debris	3.J
Fire Extinguishers Inside Containment	3.K
Inappropriate exposed materials identified inside the RCS Loop rooms	3.L
Kaowool damming material for gap seal found in Unit 1 Containment	3.M
Nonconformance Report from PCI	3.N
Confirmed presence of Kaowool damming material fro gap seal in Unit 2 Containment	3.O

The schedule for close-out of Downstream Effects Evaluations, Fuel and these activities is the third quarter of 2010.

Section 3.0 Specific Information Regarding Methodology for Demonstrating Compliance

Sections 3.a through 3.p, below, provides the information to support NRC staff verification that corrective actions to address Generic Letter 2004-02 are adequate. The format and content is in accordance with the guidance in the NRC Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, dated November 21, 2007. [Ref. 1.H].

NRC review guidance [Ref. 1.I] regarding the areas of chemical effects, coatings, and head loss testing was considered in the analysis and testing where applicable.

Responses to NRC Letter dated July 15, 2009, Request for Additional Information Regarding Response to Generic Letter 2004-02, " Potential Impact of Debris Blockage on Emergency Recirculation During Design-basis Accidents at Pressurized-water Reactors" [Ref. 1.K] are denoted in the margin (e.g. RAI #). Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L] and August 10, 2009 public conference call [Ref. 1.N].

Section 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.

CPNPP is a two unit station and the Unit 2 containment layout is a mirror image of Unit 1. Although the types of insulation are consistent between units, there are some differences in the amount of insulation and other potential debris (e,g, coatings, labels). Therefore, both units were evaluated and compared to assure any pertinent unit differences are identified and addressed. ER-ME-118, "Debris Source Inventory Confirmatory Walkdown Report for Comanche Peak Steam Electric Station - Unit 1", Revision 0 [Ref. 5.A] and ER-ME-119, "Report on Comanche Peak Steam Electric Station Unit 2 GSI-191 Debris Source Term Confirmatory Walkdown", Revision 0 [Ref. 5.B] were performed, and both were used in the debris generation analysis.

Break selection is documented in ALION-CAL-TXU-2803-03, Comanche Peak Recirculation Sump Debris Generation Calculation [Ref. 7.A.2].

Section 3.a.1 for LOCA and Section 3.a.2 for secondary breaks, below, describe and provide the basis for the break selection criteria used in the evaluation and the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance.

3.a.1 LOCA Break Selection

Emergency sump recirculation is required to meet 10CFR50.46 [Ref. 9.A] for a spectrum of loss of coolant accidents. Therefore, break selection was performed consistent with NEI 04-07 [Ref. 4.A], also known as the Guidance Report (GR), to assure bounding breaks were identified and evaluated. The NRC Safety Evaluation by the Office of Nuclear Reactor Regulation related to NRC Generic Letter 2004-02, Revision 0, December 6, 2004 is Volume 2 of NEI 04-07, also known as the Safety Evaluation (SE).

Break selection was performed with two considerations governing the approach. The first consideration is that a determination of the worst break location with respect to maximum debris generation and transport was necessary to support performance of the analysis. Section 3.3.4.1 in the GR recommends that a sufficient number of breaks in each high pressure system that relies on recirculation be considered to ensure that the breaks that bound variations in debris generation with respect to the size, quantity, and type of debris are identified. The following break locations were considered:

- Break No. 1: Breaks in the RCS with the largest potential for debris

  Breaks in all 4 loops and in the pressurizer surge line were evaluated. Breaks in Loop 4 and in the surge line generated the most debris

- Break No. 2: Large breaks with two or more different types of debris

  All of the breaks in Break No. 1 generated two or more types of debris

- Break No. 3: Breaks with the most direct path to the sump

  A break in the 3" letdown line located in the Letdown Orifice Valve Room has the most direct path to the sump.

- Break No. 4: Large breaks with the largest potential particulate debris to insulation ratio by weight

  The quantity of particulate is due to coatings and latent debris and is essentially independent of large break location. Loop 3 has the least amount of insulation.

- Break No. 5: Breaks that generate a "thin bed" – high particulate with 1/8 inch fiber bed

  The bounding large break LOCA in Loop 4 generates enough fiber to form a theoretical thin bed.

The CPNPP licensing basis documented in the FSAR is that all LOCA breaks 2 inches and over are contained within the secondary shield walls as shown on CPNPP Flow Diagrams [Ref. 2.B]. From Section 3.3.4.1, Item 7 of the NEI 04-07 SE [Ref. 4.A], piping under 2 inches diameter can be excluded when determining the limiting break conditions. Therefore, the locations where LOCAs can occur are limited by the design.

Exception(s) Taken to GR and SE for Break Selection - For break selection, the only exception taken to the GR and SE was the use of the "every five feet" criteria described in Section 3.3.5.2 of the SE. Due to the configuration of CPNPP, the overlapping Zones of Influence (ZOIs) essentially covered the same locations. The approach used was to determine the limiting debris generation locations (based on ZOI) and then determine the break location that would provide this debris. This simplification of the process did not reduce the debris generation potential for the worst case conditions as described in Section 3.3 of the GR and SE.

CONSERVATISM - This break selection methodology results in identifying the worst debris generation break for each type of debris rather than some combination of debris.

CPNPP is a low fiber plant because thermal insulation utilizes reflective metallic insulation (RMI). Low density fiberglass (LDFG) insulation is limited to anti-sweat insulation on cold water piping. The largest quantity of debris is RMI from a Loop 4 LOCA. Although the largest quantity of debris would be from RMI, the presence of such debris is actually beneficial to the new emergency sump strainer design (See Section 3.f for additional information). The greatest challenge to post-accident sump performance comes from fibrous and particulate debris.

CONSERVATISM - The break selection was performed to bound both units for each debris source.

For a break in the loop compartments, the Unit 2 Loop 4 Hot Leg break generates the largest amount of fiberglass as compared to breaks in the other loop compartments. The break in the Unit 2 Loop 4 Surge Line generates the largest amount of Min-K as compared to the primary breaks in the Loop compartment. A Unit 1 Loop 1 Cold Leg break generates the largest amount of lead shielding blanket debris.

Small break LOCAs outside the loop compartments do not generate significant quantities of fibrous debris. Therefore, large break LOCAs bound all small break LOCAs for debris sources and debris generation.

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3.a.2 Secondary Line Break Selection

Secondary line breaks were considered in the evaluation (i.e., main steam lines, main feedwater lines, and steam generator blowdown lines) in order to address technical concerns with respect to containment heat removal during sump recirculation.

As noted in Section 2.1, emergency sump recirculation is not required to meet 10CFR50.46 [Ref. 9.A] for secondary high energy line breaks. Core cooling for these design basis events is provided by the auxiliary feedwater and main steam system, not the emergency core cooling system (ECCS).

Regulatory Guide 1.82, Water Sources for Long-term Recirculation Cooling Following a Loss-of-Coolant Accident, Revision 3 [Ref. 9.G] states: "*Consistent with the requirements of 10 CFR 50.46, debris generation should be calculated for a number of postulated LOCAs of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated LOCAs are calculated. The level of severity corresponding to each postulated break should be based on the potential head loss incurred across the sump screen. Some PWRs may need recirculation from the sump for licensing basis events other than LOCAs.* ***Therefore, licensees should evaluate the licensing basis and include potential break locations in the main steam and main feedwater lines*** *as well in determining the most limiting conditions for sump operation.*"

Consistent with RG 1.82 R3, Comanche Peak Engineering evaluated the potential break locations in the current licensing basis and concluded that LOCA breaks are bounding for all debris and debris types.

The CPNPP licensing basis for break selection for secondary line breaks is Regulatory Guide 1.46 [Ref. 9.S] and BTP MEB 3-1 [Ref. 9.H] in accordance with GDC-4 as documented in the FSAR Section 3.6B [Ref. 2.B]. The NRC Staff position in NEI 04-07 SE Section 3.3.4.1 [Ref. 4.A] is that the break locations evaluated in the licensing basis "...may not have been defined specific to sump performance" and "...could not have anticipated the range of concerns identified in the course of resolving GSI-191." However, the NRC's backfit analysis in Generic Letter 2004-02 was based on 10CFR50.46, GDC 35, GDC 38, and GDC 41 which are not applicable to secondary pipe breaks. For CPNPP, sump performance was specifically reviewed in NUREG-0797, Supplements 9 and 11 [Ref. 2.L] with respect to insulation and coating debris effects on sump performance. In Safety Evaluation Report (SER) Supplement 9, Appendix L, the NRC Staff addressed insulation debris as evaluated in the Gibbs & Hill Report, "Evaluation of Paint and Insulation Debris Effects on Containment Emergency Sump Performance," [Ref 2.M]. That assessment was based on GDC-4 criteria for break selection.

In NUREG-0797, SER Supplement 21 [Ref. 2.L], Section 3.6.2.5, the NRC approved the request to eliminate from design consideration those pipe breaks generally referred to as "arbitrary intermediate breaks." Arbitrary intermediate breaks (AIBs) are defined as those break locations that, on the basis of pipe stress analysis results, are below the stress and fatigue limits specified in Branch Technical Position (BTP) PIEB 3-1 (NUREG-0800), but are selected to provide a minimum of two postulated breaks between the terminal ends of a piping system. Comanche Peak specifically requested NRC approval of the application of alternative pipe break criteria to high energy piping systems both inside and outside containment, excluding the reactor coolant system primary loop, to exclude the dynamic effects (pipe whip, jet impingement, and compartment pressurization loads) associated with AIBs for the Comanche Peak design basis.

As described in the SER, the elimination of the dynamic effects does not affect the environmental analysis for equipment qualification. Secondary line breaks are postulated at locations that result in the most severe environmental consequences.

Therefore, CPNPP has not changed its licensing and design basis for break selection in secondary piping for the purposes of sump performance. This position is in accordance with the GR Section 3.3.4.1 [Ref. 4.A]. However, because the Containment Spray System would operate in the recirculation mode following a secondary line break, CPNPP elected to evaluate sump performance using the same break selection criteria as for LOCA. Exceptions to other parts of the GR and SE based on the CPNPP licensing basis for secondary line breaks are justified where taken.

In recognition of the NRC technical concerns, CPNPP has performed evaluations of secondary pipe break locations consistent with the methodology being used for LOCA as described in 3.a.1, above [Ref. 7.A.2]. Therefore, break selection was performed to assure bounding breaks were identified and evaluated.

The following break locations were considered:

- Break No. 1: Breaks in the secondary with the largest potential for debris

Included in Break No. 2 for secondary breaks.

- Break No. 2: Large breaks with two or more different types of debris

  For a secondary side break with two or more different types of debris, the break in the El. 860' Containment Cooling Unit area generates the largest amount of fibrous debris and the break in the Main Steam Penetration area generates the largest amount of Min-K and about 40% of the fiberglass that is generated for the Containment Cooling Unit area break.

<u>CONSERVATISM</u> - The break selection for Break No. 2 is not required by the CPNPP Current Licensing Basis.

- Break No. 3: Breaks with the most direct path to the sump

  In addition to Break No. 2, a break in the Loop 4 Feedwater line in the Loop Compartment generates a large amount of Min-K and was considered since it is closest to the sumps.

- Break No. 4: Large breaks with the largest potential particulate debris to insulation ratio by weight

  For a secondary side break, the break in the Main Steam Penetration area generates the largest ratio of particulate to insulation.

- Break No. 5: Breaks that generate a "thin bed" – high particulate with 1/8 inch fiber bed

  The bounding secondary line break generates enough fiber to form a theoretical thin bed.

<u>CONSERVATISM</u> - This break selection methodology for secondary line breaks results in debris generation beyond the design and licensing basis. See Reference 2.R for a detailed discussion.

Section 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.

Zones used for walkdowns and debris generation are shown on Figures 3.b-1 through 3.b-5 in Attachment E.

Debris generation is documented in ALION-CAL-TXU-2803-03, Comanche Peak Recirculation Sump Debris Generation Calculation [REF. 7.A.2].

The debris generation evaluation consisted of two primary steps:

- Determine the Zone of Influence (ZOI) in which debris is generated.
- Identify the characteristics (size distribution) of the debris

The ZOI was defined as the volume about the break in which the jet pressure is greater than or equal to the destruction damage pressure of the insulation, coatings, and other materials impacted by the break jet.

Both the GR and SE define the ZOI as spherical and centered at the break site or location. The radius of the sphere is determined by the pipe diameter and the destruction pressures of the potential target insulation or debris material. All potentially important debris sources (insulation, coatings, fixed, etc.) within the ZOI were evaluated.

Section 4 of the GR allowed for the development of target-based ZOIs, taking advantage of materials with greater destruction pressures. The CPNPP evaluation used multiple ZOIs at the specific break location dependent upon the target debris. The destruction pressures and associated ZOI radii for common PWR materials were taken from Table 3-2 of the NRC SE [Ref. 4.A].

Materials that do not have applicable experimental data or documentation were conservatively assumed to have the lowest destruction pressure adopted. That destruction pressure is equivalent to a 28.6D ZOI. See Section 3.b.2.4 on Radiant Energy Shielding (RES) below.

Robust barriers consisting of structures and equipment that are impervious to jet impingement were utilized in the evaluation. Per the guidance given in Section 3.4.2.3 of the SE, when a spherical ZOI extends beyond a robust barrier, the barriers may prevent further expansion of the break jet but they can also cause deflection and reflection. In Section 3.4.2.3, the NRC SE states that when a spherical ZOI extends beyond robust barriers such as walls or encompasses large components such as tanks and steam generators, the extended volume may be conservatively truncated. The SE also stipulates that "shadowed" surfaces of components should be included in the analysis. These approaches were utilized within the CPNPP evaluation.

CONSERVATISM - No credit for shadowing by platforms, grating, supports, or other equipment was taken.

3.b.1 LOCA Debris Generation

The following break locations and debris generation were considered:

LOCA within the steam generator compartments (reactor coolant system loop rooms)

- RMI
- Min-K insulation
- LDFG (low density fiberglass) insulation
- Lead Shielding Blankets
- Coatings

See Section 3.h for coatings.

3.b.1.1 RMI (Reflective Metallic Insulation)

The CPNPP original specification for RMI was for Diamond Power Mirror® RMI insulation. Unit 1 steam generator RMI was replaced with Transco RMI during steam generator replacement in 2007. However, Unit 2 still has the original insulation. There are no significant unit differences which would affect the amount of RMI. The quantity of RMI was calculated based on the original insulation for Unit 1 which bounds both units.

Therefore, the damage pressure for the RMI is assumed to be 2.4 psi with a 28.6D ZOI corresponding to "Mirror® with standard bands" in Table 3-2 of the NRC SE [Ref. 4.A]. For

LOCAs, the size distribution for RMI was assumed to be 75 % small pieces and 25% large pieces consistent with the NEI GR. Small pieces are defined as pieces 4 in. square and less in size.

Given the 31 in. inside diameter of the cross over legs, the resulting ZOI radius is 28.6 * 31 in. = 886.6 in. = 73.9 ft which completely envelopes the steam generator, reactor coolant pump, and piping in the Loop compartments (See Figure 3.b-6 in Attachment E). Regardless of whether the break is located on the hot legs, cold legs, or cross over legs, the ZOI would encompass the entire compartment. Therefore the results presented are bounding for each break location.

Loop 1:	48,874 ft^2
Loop 2:	48,184 ft^2
Loop 3:	48,178 ft^2
Loop 4:	51,810 ft^2
14 in. Surge Line:	32,776 ft^2

These LBLOCA quantities bound small break LOCAs.

3.b.1.2 Min-K insulation

The Min-K insulation is installed ¼ inch thick and encased in Type 304 Stainless Steel not to exceed a total thickness of 0.5 inches [Ref. 8.A.2]. An analysis of the Min-K encapsulation was performed by Calculation ME-CA-0000-5331 [Ref. 7.F.24] which concluded the Min-K cassettes are structurally equivalent to Transco RMI; therefore, the ZOI for CPNPP encapsulated Min-K cassettes is equivalent to Transco RMI. [Note: See Figure 3.c-1 for a cut sample of the encapsulated Min-K insulation used at CPNPP.]

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The cut away sample encapsulation was measured to be 18 gauge (about 0.05" thick), and is internally reinforced circumferentially at each longitudinal end of the cassette. At each end of a semicircular piece, the outer plate is bent, and welded to the inner plate to provide blanket containment without a seam. There are no open seams anywhere on the semicircular pieces (i.e., the Min-K insulation is entirely encapsulated within the enclosed cassette).

The damage pressure of 190 psi for Transco RMI in Table 3-1 of NUREG-6808 [Ref. 9.P] was obtained from "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Bulletin 96-03 Boiling Water Reactor Owners Group Topical Report NEDO-32686, 'Utility Resolution Guidance for ECCS Suction Strainer Blockage,' " Docket No. PROJ0691, August 20, 1998. Air-jet testing is discussed in Section 3.2.1 of NUREG-6808. RMI sheaths that were half the 0.050 inch thickness of the CPNPP Min-K encapsulation were tested. No RMI sheath failed during airjet testing. RMI failures occurred due to separation of the outer sheath from the ends. Therefore, air jet testing targeted seams and joints. Secondary effects were considered to be insignificant.

Appendix B (Page B-5) of the SER for the Utility Resolution Guidance for ECCS Suction Strainer Blockage (URG) [Ref. 11A] states that the tested Transco insulation assigned a damage pressure of 190 psi was the "TPI 0.024-inch sheath solid end (stainless steel) with latch and strike closures."

The Air Jet Impact Testing of Fibrous and Reflective Metallic Insulation Report is included in Volume 3 of the URG. Tests 20-1 and 20-2 were of RMI with 0.024 inch sheaths and solid end panels. The tested RMI was fastened by rivets and tack welds (at 3 inch centers maximum). No penetrations of the cassette sheets occurred during testing which means the damage pressure would be greater than tested.

The CPNPP encapsulation has a 0.050 inch thick sheath and solid end panels. The panels are seal welded. Both the thickness of the sheath and the continuous seal weld assure that the encapsulation is more robust than the tested RMI. In addition, the Min-K encapsulation is only 0.50 inches thick giving it a much smaller profile than RMI.

<u>CONSERVATISM</u> - Because the damage pressure for Transco RMI is conservative and the CPNPP Min-K encapsulation is significantly more robust than the tested Transco RMI, use of the damage pressure assigned Transco RMI is a significant conservatism.

Alion Science & Technology performed a third party independent review of Calculation ME-CA-0000-5331, GSI-191 Structural Evaluation of Min-K Insulation Cassettes [Ref. 7.A.17] and provided the following assessment:

> "The calculation is largely comparative in nature, drawing physical design parallels between Transco Products Incorporated (TPI) Reflective Metal Insulation (RMI) and Min-K insulation cassettes. These comparisons are intended to illustrate the robust design of the Min-K cassettes thereby precluding concerns relative to the destruction of the fibrous blanket contained within.
>
> "The calculation identifies that Air Jet Impact Testing was performed on a variety of RMI

samples as manufactured by Transco. The metallic sheathing on the tested samples ranged in thickness from 0.024 in. to 0.062 in.. Post test inspection of the RMI, which was exposed to surface pressures ranging from 4 to 600 psig, revealed that penetration of the metallic sheathing did not occur. The failure mechanisms associated with the generation of transportable debris are identified as latch failure and failure of rivets and spot welds that join the RMI cassette ends and sheathing material. It is unclear if maintaining the latch integrity would prevent failure of the mechanical joints. However, this is inconsequential since the ultimate dynamic that generates debris is the jet stream interaction with the exposed fiber and particulate insulation materials. Min-K cassette construction does not utilize the spot welded/riveted connections that are evident in the RMI samples. Close examination of the Min-K cassettes reveals that continuous seal welds are used for joining the metallic plates that form the cassette structure. None of the fibrous or particulate insulation material is exposed or visible in the final assembly.

"Our review concurs with the conclusion of the calculation. We would suggest that descriptions related to the non-critical nature of the sheathing thickness could be reworded. The test information available suggests that insulation sheathing material in a thickness range of 0.024" to 0.062" does not exhibit signs of rupture at the jet pressures tested. However this does not suggest that the sheathing thickness is "not critical". It does however provide sufficient evidence that the specific Min-K cassette thickness of 0.050 in. will maintain integrity of the assembly under similar stress thereby precluding the generation of transportable debris. This distinction does not alter the conclusion stated in the calculation."

The damage pressure for the Transco RMI is 114 psig with a 2.0D ZOI corresponding to "Transco RMI" in Table 3-2 of the NRC SE [Ref. 4.A]. Therefore, Min-K will have a ZOI of 2.0D. The size distribution for Min-K was assumed to be 100% fines in accordance with the SE.

- Loop 1 (all breaks): 0.0 ft^3
- Loop 2 (all breaks): 0.0 ft^3
- Loop 3 (all breaks): 0.0 ft^3
- Loop 4 (hot leg break only): 0.34 ft^3
- Loop 4 (all other breaks) 0.0 ft^3
- Pressurizer Surge Line break: 0.56 ft^3

3.b.1.3 LDFG (low density fiberglass) Insulation

Plant documents and specifications regarding the physical properties and installation methods of the fiberglass insulation show that it is used in anti-sweat applications on component cooling [CC] and chilled water [CH] piping. The anti-sweat insulation is Johns-Manville MICRO-LOK 650, Owens-Corning Fiberglass AST/SSLII Pipe Insulation, or Knauf Fiber Glass Pipe Covering.

Anti-sweat insulation on component cooling water lines and chilled water lines less than 2 inches is 1-1/2 inches thick. The anti-sweat insulation on chilled water lines 2 inches and greater is 2 inches thick. Insulated equipment, piping, fittings, valves, etc. inside the containment building are encapsulated with stainless steel metal jacketing. Jacketing used inside the containment building is type 304 stainless steel. The stainless steel is 0.010 inches thick. The jacketing is secured with stainless steel straps ½-inch wide by 0.016-inches thick, on 12" maximum, centers. Since only one layer of jacketing is provided, destruction pressures will be lower than for jacketed insulation with "sure hold bands".

The insulation materials used in anti-sweat applications at CPNPP are bound fiberglass products with densities ranging from 3.3 to 4.9 lbs/ft^3. Low density fiberglass (LDFG) materials such as Nukon™, Thermal-Wrap™, and Knauf™ have densities of 2.4 lbs/ft^3 and high density fiberglass materials such as Temp-Mat and Insulbate have densities on the order of 11.8 lbs/ft^3.

The moderately higher density (3.3 to 4.9 lbs/ft^3) of the CPSES anti-sweat insulation will result in a higher damage pressure than that for the lower density fiberglass products. For example, the destruction pressure for NUKON (density of 2.4 lb/ft^3) is 6 psig and the destruction pressure for Temp-Mat (density of 11.8 lb/ft^3) is 10.2 psig. Since low density fiberglass has a lower destruction pressure than higher density insulation (i.e. CPSES anti-sweat insulation), it is conservative to model the anti-sweat insulation as Nukon™, Thermal-Wrap™, and Knauf™ LDFG.

Consistent with the recommendation in Section 4.2.4 of the SE, a 4-category 3-ZOI based size distribution for the LDFG was developed by Alion [Ref. 7.A.16] based on air-jet impact tests (AJIT) data.

The debris generation calculation used the following 4-category 3-ZOI based size distribution for the LDFG.

LDFG Debris Size Distribution Within Each Zone for LOCA			
Size	18.6 psi ZOI (7.0 L/D)	10.0-18.6 psi ZOI (11.9-7.0 L/D)	6.0-10.0 psi ZOI (17.0-11.9 L/D)
Fines (Individual Fibers)	20%	13%	8%
Small Pieces (< 6" on a side)	80%	54%	7%
Large Pieces (> 6" on a side)	0%	16%	41%
Intact Blankets	0%	17%	44%

A comparison of the insulation quantities by location for each unit showed that Unit 2 bounds Unit 1 and essentially all LDFG in a loop room could become debris.

Break	Quantity Destroyed	Fines	Small Pieces	Large Pieces	Intact Pieces
Loop 4 Hot Leg (Loop 4 Cold Leg) (Loop 4 Crossover Leg	42.42 ft^3	7.16 ft^3	29.01 ft^3	3.03 ft^3	3.22 ft^3
Loop 3 All Locations	34.8 ft^3	6.35 ft^3	25.56 ft^3	1.40 ft^3	1.49 ft^3
Loop 2 All Locations	34.95 ft^3	5.53 ft^3	22.54 ft^3	3.34 ft^3	3.54 ft^3
Loop 1 All Locations	33.11 ft^3	6.62 ft^3	26.49 ft^3	0.00 ft^3	0.00 ft^3
14 in. Surge Line	42.42 ft^3	4.32 ft^3	10.34 ft^3	13.4 ft^3	14.36 ft^3

3.b.1.4 Lead Shielding Blankets

Permanent lead shielding is installed on portions of the pressurizer spray line. The lead wool blankets are Lancs Industries; "HT" Series lead wool blankets consisting of lead wool with an Alpha Maritex Style 8459-2-SS silicon impregnated fiberglass outside cover encapsulating Lancs Industries, Inc. lead wool. Each blanket is 1 ft x 4 ft with the 4 ft dimension wrapped around the pipe giving one blanket per linear foot. The cover contains 5.4 lbm total fabric per blanket which equates to 0.06875 ft^3 per blanket. The fabric cover contains 81% fiberglass. Each blanket contains a 1 ft x 4ft x 1 in. blanket of lead wool which equates to 40 lbs of lead or 0.33 ft^3 of lead wool.

Westinghouse report WCAP-16727-NP [Ref. 6.E] documents the results of destruction testing for the installed lead blankets currently in use in plants. The report also documents the spherical equivalent ZOI's based on the experimental data. The same lead blankets at CPNPP were also utilized in destruction testing; therefore the results in WCAP-16727-NP are applicable to CPNPP.

RAI 2 The destruction test configuration used five (5) blowdown tests: one with a hanging blanket on an open back test rig and four (4) with a hanging blanket on a closed back test rig. For example, lead blanket specimen #2 was mounted 8.25 inches (1.25D) from the nozzle to a closed back test rig (See Attachment E, Figure 3.b-9). A single blanket was held by metal hooks through the blanket grommets on a flat backing plate. The solid back assured that the blanket was held flat in the high pressure region of the jet. See Figures 3.b-10, 3.b-11, and 3.b-12 for the debris from the Wyle test 2.

NOTE: For comparison, see Figure 3:b-13 for the lead blanket cover debris use in CPNPP strainer qualification testing (Section 3.f).

See Attachment E, Figure 3.b-8 for the Comanche Peak installed configuration. The CPNPP blankets are installed on piping in multiple layers which exposes less blanket surface area to the jet than the test configuration. CPNPP uses blankets that are secured with substantial stainless steel bands and does not rely on the blanket grommets. It was concluded that utilizing the results on the WCAP destruction testing are considered to be conservative because of the robust installation of the blankets at CPNPP. Reference 6.E recommends two ZOI's for the lead blankets: 3.0D ZOI and 3.0D to 5.0D ZOI. Based on the description of test observations in the WCAP, a 4-category 2-ZOI based size distribution for the lead blankets has been calculated.

<u>CONSERVATISM</u> - No credit was taken for the Comanche Peak configuration with multiple layers, stainless steel banding, and rounded profile to reduce debris generation. The conservatively calculated debris was also used in the calculation of chemical precipitates (Section 3.o). This is a significant conservatism.

Within the 3.0D ZOI, based on review of test observations, it is assumed that 100% of the cover and lead wool are destroyed into small fines. Within the 3.0D to 5.0D ZOI test observations discuss that 25% of the material was removed from the outer cover and 10% of the material was removed from the inner cover. Since the lead blankets have double layers of the fiberglass cover, this equates to 35% total fines. The test observations also state that there was one 10 in. section and one 2 in. section of the outer fiberglass cover torn from the back cover. The volume of the outer fiberglass cover is 0.04625 ft^3 (0.037 in. thick) and the volume of the inner cover is 0.0225 ft^3 (0.018 in. thick) for a total of 0.06875 ft^3. Assuming that the pieces destroyed are 10 inches square and 2 inches square, each destroyed piece makes up 3 % ([10 in. * 10 in. * 0.037 in./12^3]/ 0.06875 ft^3) and 0.1 % ([2 in. * 2 in. * 0.037 in./12^3]/ 0.06875 ft^3) of the total fiberglass volume for the blanket. The piece that is 2 in. is considered to be in the small pieces category however 0.1 % destruction is considered negligible. The piece that is 10 in. is considered to be in the large pieces category of greater than 6 in. on a side. Based on test photos, it is clear that the remaining lead blanket is not destroyed and remains on the target. Therefore, 62 % of the lead blanket cover is not destroyed and is not available for transport.

The test observations regarding the lead wool state that approximately 5% of the lead wool exited the blanket. Therefore, 5% of the lead wool is destroyed as fines between the 3.0D to 5.0D ZOI. Based on test photos, it is clear that the remaining lead wool is not destroyed and remains on the target. Therefore, 95% of the lead wool is not destroyed and is not available for transport.

Lead Blanket Fiberglass Cover Debris Size Distribution Within Each Zone		
Size	3.0D ZOI	3.0D to 5.0D ZOI
Fines (Individual Fibers)	100%	35%
Small Pieces (< 6 in. on a side)	0%	0%
Large Pieces (> 6 in. on a side)	0%	3%
Intact Pieces	0%	0%
Remains on Target	0%	62%

Lead Wool Debris Size Distribution Within Each Zone		
Size	3.0D ZOI	3.0D to 5.0D ZOI
Fines (Individual Fibers)	100%	5%
Small Pieces (< 6 in. on a side)	0%	0%
Large Pieces (> 6 in. on a side)	0%	0%
Intact Pieces	0%	0%
Remains on Target	0%	95%

Unit 1 is bounding for Lead Wool Shielding debris loads because the Unit 1 piping has more layers than Unit 2 (Loop 1 in Unit 1 has 3 layers while both Loops 1 and 4 in Unit 2 only have 2 layers). Loops 1 and 4 have lead wool shielding on the 4" pressurizer spray piping so these two loops on Unit 1 were evaluated.

Lead Blanket Fiberglass Debris		
Break	Fiberglass Cover Within ZOI	Total Actually Destroyed
Loop 1 (crossover leg break)	0.1 ft^3 (7.9 lb)	0.038 ft^3 (3.0 lb)
Loop 1 (cold leg break)	0.89 ft^3 (70.2 lb)	0.39 ft^3 (30.77 lb)
Loop 4 (crossover leg break)	0.067 ft^3 (5.2 lb)	0.026 ft^3 (1.98 lb)
Loop 4 (cold leg break)	0.57 ft^3 (44.6 lb)	0.25 ft^3 (19.68 lb)

Lead Wool Debris		
Break	Lead Wool Within ZOI	Total Actually Destroyed
Loop 1 (crossover leg break)	0.6 ft^3 (72 lb)	0.03 ft^3 (3.6 lb)
Loop 1 (cold leg break)	5.3 ft^3 (642 lb)	0.74 ft^3 (89.1 lb)
Loop 4 (crossover leg break)	0.4 ft^3 (48 lb)	0.02 ft^3 (2.4 lb)
Loop 4 (cold leg break)	3.4 ft^3 (408 lb)	0.48 ft^3 (58.4 lb)

3.b.2 Secondary Line Break Debris Generation

The following break locations and debris generation were considered:

Main Steam Line Breaks in the Containment Annulus and Penetration Area

- RMI
- Min-K insulation
- LDFG insulation
- RES (Radiant Energy Shielding)
- Coatings

See Section 3.h for coatings.

Exception(s) Taken to GR and SE for Debris Generation/Zone of Influence

The ZOI values provided in the NRC SE [Ref. 4] are based on HELB conditions associated with primary RCS breaks at approximately 2250 psia and 535 F. These conditions represent subcooled water that flashes into a two-phase jet. Secondary system conditions are much more similar to Boiling Water Reactor system condition of approximately 1000 psia and 570 F which are saturated steam conditions. Therefore, the ZOI values for the potential debris materials exposed to secondary system breaks were calculated using the BWR Owners' Group Utility Resolution Guidance (URG) methodology [Ref. 11.A].

3.b.2.1 RMI insulation

The destruction pressure for the RMI is given as 4 psig corresponding to "Mirror® with standard bands" in Table 2 of the URG [Ref 11.A]. As specified by Note 3 to Table 2 of the URG, the destruction pressure for RMI is based on RMI installed on a pipe of 12 inch nominal diameter. The destruction pressure for RMI varies as a function of radius of the target according to the following relationship:

P_{dest} (i) = P_{dest} 12" pipe $\{r_{12"\ pipe} / r_{target}\}$
Where: P_{dest} (i) = the destruction pressure for RMI of outer radius r_{target}
$r_{12"\ pipe}$ = the outer radius for RMI installed on a 12 in. pipe = 7.04 in.
r_{target} = the outer radius for RMI installed on the target pipe.

The ZOI for secondary system HELBs is:

$$r/D = (7149 * \{7.04 \text{ in.}/ r_{target}\} /4.19)^{1/3}$$
$$= (11.95\{7.04 \text{ in.}/ r_{target}\})^{1/3} \text{ use } 12.0\{7.04 / r_{target}\})^{1/3}$$

The size distribution for RMI was assumed to be 50% small pieces and 50% large pieces consistent with the URG.

3.b.2.2 Min-K insulation

The destruction pressure for the Min-K is the same as Transco RMI which is given as 190 psig in Table 2 of the URG [Ref 11.A]. The correction factor for destruction pressures above 60 psig is 0.4. The ZOI for secondary system HELBs is:

$$r/D = (0.4*965/4.19)^{1/3}$$
$$= 4.5$$

Recognize that using the URG methodology for the secondary side breaks results in a larger Min-K ZOI for the secondary side break than for the primary side which may be conservative.

3.b.2.3 LDFG (low density fiberglass) insulation

The 4-category 3-ZOI based size distribution for the LDFG discussed in Section 3.b.1.3 was modified by calculating new ZOIs:

For the destruction pressure of 18.6 psi, use the "A" constant for 17 psi:
$r/D = (3238/4.19)^{1/3}$
$= 9.18$, use 9.2

For the destruction pressure of 10.0 psi:
$r/D = (4708/4.19)^{1/3}$
$= 10.4$

For the destruction pressure of 6.0 psi:
$r/D = (6137/4.19)^{1/3}$
$= 11.36$, use 11.4

The revised 4 -category 3-ZOI based size distribution for the LDFG is:

LDFG Debris Size Distribution Within Each Zone for Secondary System HELBs			
Size	18.6 psi ZOI (9.2 L/D)	10.0-18.6 psi ZOI (10.4-9.2 L/D)	6.0-10.0 psi ZOI (11.4-10.4 L/D)
Fines (Individual Fibers)	20%	13%	8%
Small Pieces (< 6 in. on a side)	80%	54%	7%
Large Pieces (> 6 in. on a side)	0%	16%	41%
Intact (covered) Blankets	0%	17%	44%

3.b.2.4 Radiant Energy Shielding (RES) Blankets

The HEMYC fire blankets are comprised of Kaowool enclosed in SilTemp blankets. No debris generation data is available for these specific fire blankets or combination of materials.

Therefore, the damage pressure for the HEMYC fire blankets will be assumed to be 4 psig which is the lowest damage pressure of materials provided in the URG and is considered conservative. The ZOI for material with a 4 psig damage pressure exposed to secondary system HELBs is:

$r/D = (7149/4.19)^{1/3}$
11.95 use 12.0

The size distribution for the HEMYC blankets was assumed to be 100% fines.

No HEMYC fire blankets are exposed to primary RCS system breaks (i.e. LOCA). This material is used in the annulus outside the secondary shield walls and is prohibited in the RCS loop rooms. This material is used as a radiant energy shield for raceways and electrical equipment. However, this material could be in the debris from certain secondary line breaks as postulated in Section 3.a. The HEMYC fire blankets are comprised of Kaowool enclosed in SilTemp blankets.

<u>CONSERVATISM</u> - The damage pressure for unjacketed Min-K and Diamond Power Mirror® insulation with standard bands in the URG is 4 psi. The damage pressure for unjacketed NUKON in the URG is 10 psi. HEMYC fire blankets would be close to unjacketed NUKON in material and construction. Therefore, assuming the lower destruction pressure is very conservative.

3.b.3 Labels and Tags

Existing labels and tags were evaluated [Ref. 3.F] and tested [Ref.s 7.A.9 and 8.D.9] for their potential impact on emergency sump performance.

Three classifications were selected for labels:

Acceptable Labels – Unqualified labels that have been tested and/or evaluated to assure they will not adversely impact the operation of the emergency sumps in containment.

Qualified Labels – Labels and their method of attachment that have been tested and/or evaluated to remain in place (attached) under design basis LOCA conditions.

Unacceptable Labels - Labels that are not Qualified Labels or Acceptable Labels. These include, but are not limited to, labels and signs made of paper, cardboard, aluminum and tape.

RAI 5 The primary equipment tagging labels for CPNPP are Series 1000 polyester labels manufactured by Electromark®. There is an estimated 1400 ft^2 of these labels in each containment. These labels have been tested by the vendor under typical LOCA conditions. Where these labels have been provided by the vendor on a stainless steel backing and both attached to the equipment by stainless steel wires, they are considered to be Qualified Labels which will not constitute potential debris. There are about 1229 ft^2 of Series 1000 labels which are not affixed by stainless steel tie wires. These labels also passed environmental testing by the vendor and are considered Acceptable Labels based on testing described in Sections 3.e.1 and 3.f.3.3. Although these labels passed environmental testing when applied to stainless steel and galvanized steel without the tie wires, some are affixed to painted surfaces. Due to the uncertainty in the types and conditions of the surfaces to which these labels are attached, it was determined these labels would be included in transport testing to confirm the classification.

Testing showed that transport of Electromark® labels to the strainer surface and blockage would not occur. These labels did not reach the strainer during transport testing. To provide additional assurance, the predominant label sizes were tested by placing them directly on the strainer surface with the strainer at design flow. Four Electromark® (Series 1000) labels (2 – 6" x 6" and 2 – 6" x 16") were firmly pressed against the strainer module surface (on top, along the side, and between disks). When pressure was released from the labels, the flow at the surface of the strainer was not sufficient to keep the labels on the surface of the strainer (labels came off due to the flow around the strainer). Therefore, it was concluded that these labels would neither transport nor cause head loss.

See Attachment C and D for pictures of transport and strainer testing of labels and miscellaneous debris.

Lamacoid labels were used during construction, and a number still remain. These were assumed to be Acceptable Labels given the design of the new sump strainer. These labels were also included in transport testing (Ref. 7.A.9 and 8.D.9) which confirmed they would not transport to the sump.

Other than the Series 1000 Electromark® and lamacoid labels, it was estimated that approximately 165 ft^2 of paper, vinyl, or other materials affixed by adhesive existed in Unit 1 with Unit 2 assumed to be similar. [Ref. 7.F.26] These were classified as Unacceptable Labels because there was no basis for acceptability at the time.

As described in Section 3.d.4, 200 square feet of sacrificial area was designated for each emergency sump strainer. Unacceptable labels are assumed to block the strainer surface in accordance with NEI and NRC guidance. The impact on the sacrificial area margin was calculated to be the area equivalent to 75% of the total of the original single sided surface area of the unacceptable labels, tags, and tape (per SER) plus 20% for uncertainty.

Steps were taken to remove obsolete labels, tags and tapes and to replace unacceptable labels and tags with acceptable materials. The quantity of Unacceptable labels was updated in June 2008 [Ref.s 7.F.27 and 7.F.28] as follows:

	Unit 1	Unit 2
Estimate	26.6 ft^2	28.8 ft^2
With 20% margin	31.9 ft^2	34.6 ft^2

The margin was added to account for uncertainties in the estimate since the only mechanism to identify these labels was by field walk downs.

RAI 4 CONSERVATISM - When calculating blockage, paper labels were assumed to not curl or degrade even though this phenomenon was observed in testing (Section 3.f.3.3). Paper tags are less than 22% of the total unacceptable labels and represent an insignificant amount of fiber. Assuming blockage of sacrificial surface area is more conservative than testing paper labels. Paper labels are likely to settle before reaching the strainer in prototypical conditions. Therefore, paper tags were not included in head loss testing.

See Section 3.e for the debris transport analysis and Section 3.f for transport testing of labels.

Section 3.c Debris Characteristics

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

Debris characteristics are documented in ALION-CAL-TXU-2803-03, Comanche Peak Recirculation Sump Debris Generation Calculation [REF. 7.A.2].

3.c.1 LOCA Debris Characteristics

3.c.1.1 RMI Insulation

The size distribution for RMI was assumed to be 75% small pieces and 25% large pieces consistent with the NEI GR [Ref. 4.A, Volume 1] and the SE Table 3-3[Ref. 4.A, Volume 2]. Small pieces are defined as pieces 4 inches square and less in size.

3.c.1.2 Min-K insulation

The size distribution for Min-K was assumed to be 100% fines in accordance with the NEI GR.

<u>CONSERVATISM</u> - 100% transport of Min-K fines was assumed as described in Section 3.e.

According to Thermal Ceramics, Inc, Min-K is comprised of 20% fiber, 65% amorphous particles (fumed silica SiO_2 with a characteristic density of 137 lb/ft^3), and 15% Titanium Dioxide (TiO_2) (with a characteristic density of 262 lb/ft^3) by weight. The constituent particulates were combined into a single equivalent particle with a density of (0.65 x 137 + 0.15 x 262)/0.8 = 161 lb/ft^3 and an average amorphous particle size of 29.8 microns.

Exception(s) Taken to GR and SE for Debris Characteristics

> According to product information from the manufacturer Thermal Ceramics, Inc, Min-K fails as 20% fiber fines and 80% particulate fines. Data provided by Microtherm was used to develop specific fiber density for Min-K. This fiber density is consistent with the characteristic densities of fiberglass material. Based on Scanning Electron Microscopy (SEM analysis of the Min-K present at Comanche Peak, the fiber has an average fiber diameter of 5 microns and the particulate has an average particle diameter of 29.8

microns [Ref. 7.A.10, See Figures 3.c-1 through 3.c-4 Attachment E]. This particle diameter is significantly different than that quoted in NEI 04-07 [Ref. 4.A]. The NEI document quotes a value such as 0.1 to 0.2 micron for a particle diameter. When referring to the MSDS sheets for the material that NEI quotes for Min-K, this measurement is actually the mean free space between the Min-K particles and hence the air space length between Min-K amorphous tufts. This is a significant difference from an actual particle measurement, and as such the NEI quoted value for Min-K is not used for the characteristics of Min-K material. The particle diameter determined by SEM is appropriately conservative.

The fibrous debris has the following characteristics:

- Macroscopic Density: 16 lb/ft^3
- Microscopic Density: 165 lb/ft^3
- Fiber Diameter: 1.6 E-05 ft

The particulate debris has the following characteristics:

- Macroscopic Density: 16 lb/ft^3
- Microscopic Density: 161 lb/ft^3
- Particle Diameter: 9.8 E-05 ft

RAI 3 As noted in NEI 04-07 Vol 2 (SE) [Ref. 4.A], Section VI.3.2.3, "No debris-generation data were available for Min-K insulation. Data from tests conducted by the OPG (NUREG/CR-6762, Vol. 3, 2002) serve as the primary source of calcium silicate debris-generation data. These tests involved impacting aluminum-jacketed calcium silicate insulation targets with a two-phase water/steam jet." and "In light of these uncertainties, it is conservative and prudent to assume that all of the Min-K insulation inside a ZOI would be pulverized to dust."

The particle size identified by the SEM analysis is consistent with the SE description of dust. The Min-K debris was assumed to be fines and was treated the same as latent debris in the analysis. 100% transport of both Min-K fiber and particulate was assumed (i.e., no credit for settling).

Note: Min-K used in testing was pulverized to form prototypical debris.

3.c.1.3 LDFG (low density fiberglass) insulation

Anti-sweat fiberglass used on cooling and cold water lines was assumed to be low density fiberglass (LDFG) similar to Nukon™, Thermal-Wrap™, and Knauf™ LDFG.

- Macroscopic density: 2.4 lb/ft^3
- Microscopic density: 159 lbm/ft^3
- Fiber diameter: 2.3 E-05 ft

3.c.1.4 Lead Shielding Blankets

The lead wool blankets are Lancs Industries "HT" Series lead wool blankets consisting of 10 lb/sq ft lead wool encased in a cover that consists of Alpha Maritex Style 8459-2-SS silicon impregnated fiberglass. See page 12 of Attachment C for a blanket used in transport testing.

The fiberglass cover contains 5.4 lbm of fabric per blanket which equates to 0.06875 ft^3 per blanket. These values are used to calculate the macro-density. The mass and characteristic size of the fiberglass fine debris is based on the Alpha Maritex Product Datasheet and the Material Safety Data Sheet for the material which provide the following characteristics:

- Macro-density: 5.4 lb / 0.06875 ft^3 = 78.5 lb/ft^3
- Micro-density: 2.4 * 62.4 lbm/ft^3 = 149.8 lbm/ft^3
- Fiber diameter: 2.3 E-05 ft

Conservatively assuming 100% of the weight is due to the lead wool, each blanket contains a 1 ft x 4 ft x1 in. layer of compressed lead wool equates to 40 lbs of lead or 0.3333 ft^3 (1 ft x 4 ft x 0.08333 ft) of lead. Thus, the density is calculated as:

- Macroscopic density = 40 lb / 0.3333 ft^3 = 120 lbm/ft^3

The microscopic density of the lead wool is based on the average density of pure lead.

- Microscopic density: 710 lbm/ft^3

The fiber diameter was provided by the vendor:

- Fiber Diameter: 10 mil = 254 microns = 8.33E-04 ft

3.c.1.5 Coatings

See Section 3.h.

3.c.2 Secondary Line Break Debris Characteristics

3.c.2.1 RMI Insulation

The size distribution for RMI destroyed by secondary system HELBs is assumed to be 50% small pieces and 50% large pieces consistent with the Utility Resolution Guidance (URG) [Ref. 11.A]. Small pieces are defined as pieces 4 in. square and less in size.

3.c.2.2 Min-K Insulation

See 3.c.1.2.

3.c.2.3 LDFG (low density fiberglass) Insulation

See 3c.1.3.

3.c.2.4 Radiant Energy Shielding (RES) Blankets

The Radiant Energy Shielding (RES) is comprised of HEMYC fire rated blankets.

The macroscopic density of the Kaowool was determined based on the CPNPP specification and the Kaowool Product Information Sheet. The microscopic density is taken from the Kaowool Material Safety Data Sheet and the characteristic size from the NEI GR.

Macroscopic density: 8.0 lbm/ft^3.
The microscopic density: 2.5 * 62.4 lbm/ft^3 = 156 lbm/ft^3
Fiber diameter: 1.1 E-05 ft

The mass and characteristic size of the SilTemp debris is based on the Ametek Product Datasheet, the Material Safety Data Sheet for the material, and the NEI GR which provide the following characteristics:

Macro-density: 18 oz/yd2 * (1lb/16 oz)(1 yd^2 /9 ft^2)/(0.030"/12) = 50.0 lb/ft^3
Micro-density: 2.2 * 62.4 lbm/ft^3 = 137.3 lbm/ft^3
Fiber diameter: 2.3 E-05 ft (Assume similar to Low Density Fiberglass)

3.c.3 Specific Surface Areas for Debris

NUREG/CR-6224 [Ref. 9.L] correlations were not performed for the final strainer design and qualification. Qualification was performed by testing. Therefore, these values are not pertinent.

Section 3.d Latent Debris

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

Containment Condition Assessments – A series of walkdowns have been completed as described in Ref. 2.A. Comprehensive containment walk downs were completed for Unit 1 during the Spring 2004 1RF10 outage. Comprehensive containment walk downs for Unit 2 were completed during the Spring 2005, 2RF08 outage. These containment condition assessments are documented in SMF-2001-002201-00 [Ref. 3.A]. Supplementary walkdowns to assess general containment conditions were performed [Ref. 5.F] as follows:

2004, September	Unit 1 and Unit 2 - at power
2005, May	Unit 1 and Unit 2 - at power
2005, June	Unit 1 - at power
2006, October	Unit 2 - 2RF09 as left (prior to Mode 4 entry)
2007, August	Unit 1 - at power (post 1RF12)
2008, October	Unit 1 - 1RF13 as left (after Mode 4 procedure entry)
2009, October	Unit 2 - 2RF11 as found (Mode 3)

3.d.1 Methodology used to estimate quantity and composition of latent debris.

The comprehensive walk downs were performed using guidance provided in NEI 02-01, "Condition Assessment Guidelines, Debris Sources inside Containment," Revision 1 [Ref. 4.B]. In addition, the Unit 2 walkdown included extensive sampling for latent debris (dust and lint) considering guidance in NEI 04-07 Volume 2 (i.e., the NRC SE) [Ref. 4.A].

Exception(s) Taken to GR and SE for Latent Debris - The methodology provided in the SE (Section 3.5) [Ref. 4.A] for collection of the debris samples was not explicitly followed for CPNPP.

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

3.d.2 Basis for assumptions used in the evaluation.

The assumption was made that any significant variation in debris density could be distinguished by visible observation which was substantiated by the correlation of the visual characterization to the sample data. This assumption is appropriate because of the large margin and conservatism in the latent debris assumptions.

3.d.3 Results of the latent debris evaluation, including amount of latent debris types and physical data for latent debris.

Based on those walkdowns, a calculation was perfomed to quantify the latent debris that could exist in CPNPP Unit 2. This calculation conservatively determined the debris loading to be just less than 91 lbm. [Ref. 5.B]

The Unit 2 estimate of latent debris bounded the Unit 1 estimate [Ref. 5.C]. The Unit 1 estimate included sampling of vertical steel and concrete surfaces which showed the contribution is not significant.

Apart from the debris collection that was performed, it was also identified that there were unqualified labels in containment. Labels are included in the scope of Sections 3.b, 3.c, 3.e, and 3.f.

CPNPP elected to use a bounding value of 200 lbm for the latent debris source term in containment.

Debris Transport - Conservative values were assumed for the composition in accordance with NEI 04-07, Section 3.5.2.3 and the SE [Ref. 4.A]. The particulate/fiber mix of the latent debris was assumed to be 15% fiber (30 lbm). The latent fiber debris was assumed to have a mean density of 94 lbm/ft^3 (1.5 g/cm^3) and the latent particulate debris a nominal density of 169 lbm/ft^3

(2.7 g/cm^3). The latent particulate size was assumed to have a specific surface area of 106,000 ft^{-1} [Ref. 9.T]. The latent debris fiber bulk density was assumed to be the same as that of LDFG which is 2.4 lb/ft^3. The characteristic size of the latent fiberglass is also assumed to be the same as LDFG or approximately 7 microns.

CONSERVATISM - Note that the assumptions for latent debris result in a significant conservatism in the quantity and characteristics of latent fiber.

Strainer Testing - The surrogates used in testing are described in Ref. 8.D.4. The fiber surrogate used for testing was Nukon. The particulate surrogate used for testing was the PCI Mix 1 . A comparison to NUREG/CR-6877 [Ref. 9.T] is provided in Ref. 8.D.4.

3.d.4 Sacrificial strainer surface area allotted to miscellaneous latent debris.

Two hundred square feet of sacrificial surface area per strainer was specified to account for miscellaneous debris, including unqualified paper labels.[Ref. 8.A.1]

Section 3.e Debris Transport

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

Debris transport is documented in ALION-CAL-TXU-2803-04, Comanche Peak Reactor Building GSI-191 Debris Transport Calculation [Ref. 7.A.3].

The calculated debris transport fractions and total quantities of each type of debris assumed to be transported the the strainers is documented in ALION-CAL-TXU-2803-06, Summary of Debris Generation and Debris Transport Results [Ref. 7.A.5].

See Attachment E for selected figures from Debris Transport Calculation [Ref. 7.A.3].

3.e.1 Methodology

Debris transport is the estimation of the fraction of debris that is transported from debris sources (break location) to the sump screens. The four major debris transport modes 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 cooling system (ECCS).

The methodology used in this analysis was based on the NEI 04-07 GR for refined analyses as modified by the NRC's SER, as well as the refined methodologies suggested by the SER in Appendices III, IV, and VI. The specific effect of each mode of transport was analyzed for each type of debris generated, and a logic tree was developed to determine the total transport to the sump screen. The purpose of this approach was to break a complicated transport problem down into specific smaller problems that could be more easily analyzed.

The first step in the transport analysis was to construct a three-dimensional CAD model of the Comanche Peak containment building based on structural drawings of the containment building. The CAD model was built from the floor of the containment building (elevation 808'-0") to a point above the operating deck (elevation 921'-9").

Figures 3.e.1-1 through Figure 3.e.1-7 show various views of the structural information contained in the model.

3.e.1.1 Blowdown, Washdown and Pool Fill Transport

RAI 7

Blowdown/Washdown

In the Comanche Peak debris transport calculation [Ref. 7.A.3], drywell debris transport study (DDTS) test data was used to take credit for small pieces of fiberglass being held up on grating as discussed in NUREG/CR-6369 [Ref. 9.K]. A conservative washdown fraction of 50% was used for small fiberglass through grating. The fiberglass fines were conservatively assumed to have 100% washdown transport with no retention on structures or grating. Since large pieces of debris would not pass through grating, the hydrogen vents (i.e. six inch diameter quartered holes in floors to assure hydrogen mixing post-LOCA), or drain holes (i.e. floor drains), and this debris would also not be readily transported across the concrete floor in upper containment, the washdown fraction for large pieces was considered to be negligible.

In Section 5.5 of the Comanche Peak debris transport calculation, debris landing on the operating deck was assumed to be washed to the RCS loop bays, refueling canal, stairwell, equipment hatch, perimeter openings, and floor drains. It was very conservatively assumed that there would be no retention for the small fiberglass debris washed down to all of these regions with the exception of the RCS loop bays. Based on the spray flow split in upper containment, 27% of the small pieces of fiberglass were determined to transport to the RCS loop bays from upper containment—18% falling directly back into the loop bays at the end of the blowdown phase, and 9% washing to the loop bays off of the concrete operating deck. Of the 27% washed to the RCS loop bays, 17% was determined to wash down with 10%held up on grating. There are a number of grated platforms in the RCS loop bays that were assumed to cover three-quarters of the loop bay area. As shown in Figure 3.e.1.1-1 through Figure 3.e.1.1-3, the actual coverage is approximately 87%.

CONSERVATISM - Although some of the debris washed down in the RCS loop bays would have to pass through two levels of grating to reach the floor, this was conservatively neglected in the analysis. only one level of grating was credited for debris retention.

At Comanche Peak, the total quantity of anti-sweat fiberglass generated for Break Loop 4 Hot Leg was determined to be approximately 42 ft^3. The average size distribution for this debris was determined to be approximately 17% fines, 68% small pieces, 7% large pieces, and 8% intact blankets [Ref. 7.A.2]. Considering just the quantity of fines and small pieces, there would be 36 ft^3 of debris with a size distribution of 20% fines and 80% small pieces. The blowdown transport fractions for fines and small pieces of fiberglass are 73% for fines, and 59% for small pieces (see Section 5.4 of the debris transport calculation) [ref. 7.A.3]. Multiplying the blowdown transport fractions by the size distributions shows that a total of approximately 22 ft^3 of small and fine fiberglass debris would be blown to upper containment with a distribution of 23% fines and 77% small pieces.

CONSERVATISM - One of the significant conservatisms in the Comanche Peak debris transport analysis is the assumption that all debris in upper containment would be washed down to the pool with the exception of a portion of small piece debris held up on grating (i.e. all debris is washed to the various grated hatches and openings without being held up on the concrete floors).

CONSERVATISM - Another significant conservatism in the Comanche Peak debris transport analysis is assuming that all debris that is not blown to upper containment would be washed back to the recirculation pool. As discussed in Appendix VI of the SE, approximately 17% of fiberglass fines and small pieces would be captured when the flow makes a 90-degree bend [Ref. 4.A, Volume 2]. Additional debris would also be captured by miscellaneous structures and grating. In the Comanche Peak debris transport analysis, approximately 10% of small fiberglass debris was determined to be captured on walls and miscellaneous structures in the steam generator compartments (see Section 5.4 of the debris transport calculation). Although fiberglass fines would be captured similar to the small pieces, no credit was taken for this capture and all of the small pieces not blown to upper containment were conservatively assumed to be washed back to the containment pool.

CONSERVATISM - Since most of the walls and structures in the steam generator compartments are shielded from the containment sprays, the majority of the debris captured on the walls and structures would be retained. Taking credit for this would reduce the overall transport fraction for fiberglass fines by approximately 10% (equivalent to the capture for small fiberglass), as well as a partial reduction in the transport for the small pieces of fiberglass. For the limiting fiberglass debris generation case, the reduction in fiberglass fines transport would result in a reduction of approximately 1 ft^3 at the strainers (42 ft^3 x 17% fines x 10% capture).

An analysis of the NUREG/CR-6369 [Ref. 9.K] washdown test data indicates that although there are some uncertainties in the approach taken, the application of the test data to hold up of small fiberglass debris on grating at Comanche Peak is conservative.

A review of conservatisms taken in various portions of the debris transport analysis and the application of data in the BWROG URG [Ref. 11.A] indicates that the uncertainties associated with the application of the NUREG/CR-6369 washdown test results are more than compensated by the conservative approaches taken in the blowdown and washdown analysis.

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Pool Fill

As described in Section 3.j.2 , the debris interceptor function during pool fill is to prevent preferential flow towards the sumps during the initial pool fill when sheeting occurs.

- Following the blowdown, as the pool starts filling, debris would tend to be washed out of the two RCS Loop Bay doors.
- During the initial high velocity sheeting phase of the fill-up period, the only directional flow outside the secondary shield wall would be toward the inactive reactor cavity. Therefore, debris would be scattered around outside the secondary shield wall and carried into the reactor cavity.
- Water would not flow preferentially to the sump strainers until the water level rises above the top of the 12 inch debris interceptors (after the sheeting phase is over), and it would take less than a minute for the sump cavities to fill.

Although, debris in the pool would be more likely to be concentrated in the vicinity of the reactor cavity entrance and around the full area outside the secondary shield wall, the debris transport calculation conservatively assumed that the debris would be distributed along the shortest paths from the location of the break to the sump strainers. See Figures 3.e.1.1-7 and 3.e.1.1-8.

The containment cross sectional area is 14314 ft^2. The spray flow of 5440 gpm from one train of CSS at the top floor elevation (El 905'-6") would be 0.7 inches per minute. Wash down of Elevation 860 (floor area 6257 ft^2) from one train of CSS at 1340 gpm (207 ft^3/min) would be 0.4 inches per minute equivalent to a 24 inch per hour rainfall. Due to the high spray flow, most debris in the path of the sprays would be washed down from upper containment relatively quickly and would reach the pool before the initiation of recirculation.

Therefore, the assumed washdown debris distribution at the beginning of recirculation (Figure 3.e.1.1-8) is conservative.

A pool fill analysis [Ref. 7.F.30] was performed to determine the flood elevation above the 808' elevation at the time that the reactor cavity is filled. The time dependent calculations show that the level at 808' rises quickly at the initial stages of the pool fill and during this time the cumulative drainage to the cavity is small compared to the input at 808'. As the level at 808' elevation increases, the cavity drainage rate increases. With maximum ECCS/CSS input, the 808' elevation reaches approximately 4.5 feet prior to the cavity filling. The maximum inactive sump fill rate is approximately 10,400 gpm. With minimum ECCS/CSS input, the 808' elevation reaches approximately 3 feet prior to the cavity filling. The maximum inactive fill rate is approximately 7,400 gpm.

During this time before the initiation of recirculation, debris will be pushed away from where water and debris enters the pool. Any debris not moving with the preferential flow to the inactive sump will be rapidly settling in the high temperature water.

Buoyancy testing of fiberglass insulation by Sandia National Laboratories [NUREG/CR-2982, Ref. 9.Q] found that fiberglass insulation readily absorbs water and sinks rapidly (from 20 to 30 seconds in 120 °F water 5 feet deep). The time needed for insulation to sink was found to be less at higher water temperatures.

Therefore, although it is reasonable to assume that there would be some debris in the vicinity of the strainers, this would primarily be RMI. Settling of almost all debris in the area to the floor prior to recirculation would be expected.

CONSERVATISM - Although it was not credited, the presence of RMI and other less transportable debris in the recirculation pool would tend to trap more readily transportable debris during pool fill reducing the overall recirculation transport.

3.e.1.2 Recirculation Transport

A three-dimensional computer aided drafting (CAD) model (e.g. Figure 3.e.1.2-1) of the Comanche Peak containment building was used to determine transport flow paths during each phase of the LOCA event. The evaluation of debris transport using CFD was used to determine the benefit of plant modifications which were implemented. (See Section 3.j for details.) The current plant design and configuration were used in the final analysis. It was assumed that becuase Comanche Peak Unit 1 and Comanche Peak Unit 2 are essentially mirror images of each other, debris transport would be the same for both units.

The Computational Fluid Dynamics (CFD) calculation for recirculation flow in the Comanche Peak containment pool was performed using Flow-3D® Version 8.2. Flow-3D® is a commercially available general purpose computer code for modeling the dynamic behavior of liquids and gasses influenced by a wide variety of physical processes.

The program is based on the fundamental laws of mass, momentum, and energy conservation. It has been constructed for the treatment of time-dependent multi-dimensional problems, and is applicable to most flow processes. The information presented above represents the debris transport that would have to be considered for mitigative capability as defined in Section 6.1 of the SER.

RAI 11 Figure 3.e.1.2-3 shows the sources of containment spray drainage that enter the containment pool that were modeled in the CFD analysis. For sources near the sump strainers, the drainage would occur in a dispersed form (e.g., droplets) from spray nozzles, from water falling from a hydrogen vent opening, and back flow from floor drains.

Approximately 107 gpm (10% of the Region D sprays) of spray and approximately 62 gpm flow from one of the 37 hydrogen vent openings fall on the Train A and Train B sumps respectively. The flow velocity for these sources was conservatively modeled as 29 ft/s. The hydrogen vent flow would only have a short free fall distance (1.25 ft since the top of the sump covers are at Elevation 814'-3" – this gives a free fall velocity to the pool surface of approximately 9 ft/s).

Approximately 50 gpm of back flow through each floor drain was also modeled.

Figure 3.e.1.2-5 shows the break flow from Loop 4 LBLOCA into the recirculation pool. Flow from a break in Loop 1 or 4 would enter the pool approximately 15 feet upstream of the train A strainer. This flow would enter perpendicular to the pool flow. The distance the flow and debris would have to travel is greater. As noted in Section 3.j, a solid panel was provided on the outboard end of the train A sump structure to divert high velocity water from direct impingement on the strainer array.

RAI 16 Figures 3.e.1.2-7 and 3.e.1.2-8 show the flow vectors for Single Train B and Single Train A operation, respectively. Essentially all flow moves around the annulus and must go around the solid panel on the end of the strainers. Then, it must make an approximately 90 degree turn to enter the first module in each strainer bank. The flow vectors must make a similar turn for each succeeding module albeit over a longer distance. Note that the covers over the sump structure in the figures obscure vectors which show the actual flow over the debris interceptors. Because the strainers have flow control integrated into their design, equal flow into and along each of the 4 banks of modules per strainer is assured. The average flow over the debris interceptor is 0.12 fps. Therefore, the flow along the length of each strainer must slow down and turn before entering the strainer.

Due to a lack of test data for the tumbling and settling of anti-sweat fiberglass, lead blanket covers, Kaowool™, lead fibers, and SilTemp™, it was assumed that these fibrous debris types are identical to Nukon™ and Thermal-Wrap™ for transport purposes. This is a reasonable assumption since the densities of these fibrous products are greater than or equal to the density of Nukon™ and Thermal-Wrap™ .

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).

Testing was performed by Alion Science and Technology on CPNPP labels, tape and other miscellaneous debris including coatings. The testing included settling tests [Ref. 7.A.6], tumbling tests [Ref. 7.A.7], and debris interceptor tests [Ref. 7.A.8] which were summarized in ALION-REP-TXU-2803-21 [Ref. 7.A.9]. The settling tests showed the labels readily settle and that settling velocity increase with temperature. The tumbling tests showed incipient tumbling velocities below 0.1 fps. Tumbling velocities ranged from 0.07 fps to 0.36 fps. Based on these results, it was decided that a full scale interceptor test would be required. No credit for settling of this debris or the debris interceptor was taken in the transport analysis.

3.e.2 Exception(s) Taken to GR and SER for Debris Transport

- A 10% erosion of fiberglass was used for smalls that were shown not capable of transport to the strainer instead of the 90% recommended in the SER based on the following.

  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 [Ref. 30]. 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 plants compared to the boiling water reactor (BWR) 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 a PWR plant like Comanche Peak, however, the break would generate debris that would either be blown to upper containment or blown directly to the floor where the pool would form. Most of the debris would not be hung up directly below the break flow where it would undergo the high erosion rates suggested by the DDTS. Any debris blown to upper containment that is not washed back down, however, would be subject to erosion by the sprays. Based on the results of the DDTS testing, a 1% erosion factor was applied for small and large piece fibrous debris held up in upper containment. The erosion mechanism for debris in the pool is somewhat different than what was tested in the DDTS.

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  A 10% erosion of fiberglass was assumed based on analysis in the debris transport calculation. Erosion testing by Alion [Ref. 7.A.13, ALION-REP-LAB-2352-77] that confirmed the 10% assumption was compared to CPNPP materials and conditions [Ref. 7.A.12, ALION-REP-TXU-4464-03] and it was concluded that the testing was applicable to CPNPP. Alion provided ALION-REP-LAB-2352-77 to the NRC on July 8, 2009 [under ML092080572].

  NUKON LDFG testing was performed in Alion's Hydraulic Test Lab Vertical Test Loop (VTL) and the lab's Transport Flume (TF). Details of these apparatuses can be found in "ALION-PLN-LAB-2352-77: Low Density Fiberglass Erosion Test Plan" which was also provided to the NRC on July 8, 2009. Since the incipient tumbling velocity is the velocity at which the debris would start moving, this velocity bounds the greatest velocity that a piece of insulation lying alone in the containment pool would experience without being included in the debris predicted to transport to the sump strainer. Therefore, it is considered the velocity that would produce the most insulation fines that would travel to the sump strainer while the piece of insulation itself would remain stationary in the pool.

Erosion of LDFG predicted to transport to the strainer is not required in the transport analysis because that debris is included in the testing. See Section 3.f for additional information.

The increased post-LOCA water temperature at Comanche Peak would have no effect on the flow erosion of fiberglass since the higher water temperature does not affect the chemical or physical reaction of the fibers with respect to physical erosion taking place.

The tests were conducted in tap water and not buffered or borated water that would be present in containment. The use of tap water is considered appropriate because the lack of chemicals such as aluminum, boron, or pH buffers will not affect the amount of fibers that would erode off of a Nukon sample with respect to flow erosion. On the contrary, the presence of some chemicals such as aluminum would actually bond to the fibers and increase the mass of the Nukon sample instead of aiding its erosion. Additionally, if turbulence is high enough to not allow settling, then the insulation debris will be transported either to the sump strainers or until it is stopped by agglomeration with other debris or by other debris capture mechanisms. In either case, since the debris will be transported to the sump strainers or captured, it will not be sitting in the open free recirculation portion of the containment pool and its flow erosion will not be significant. The erosion factor is applied to the portion of the small and large pieces of fiber in the pool that are subjected to a low enough turbulence to allow settling and low enough velocity (i.e. a velocity lower than the corresponding incipient tumbling velocity) to avoid tumbling. A combination of the above two conditions applies to a portion of the pool that is calmer than the rest of the areas.

As discussed in Section 4.0 of ALION-REP-TXU-4464-03, it was observed that the term fiber "erosion" to describe the loss of weight is more aptly described as fiber "attrition." The fibers themselves that make up the samples do not actually erode down into fines as the water passes across them; the "erosion" is actually the release of loosely bound constituent fibers that are washed away by the flowing water. Alion's experience with fibrous debris during other types of tests is evidence of this behavior. During testing, the following is usually observed that when the clumps of fiber subjected to a velocity such that an erosion factor is applicable (as discussed above) on the floor of a test pool:

- Individual fibers tend to clump which is evident by the measures taken by the Alion Hydraulics Laboratory to keep them apart during testing.
- Individual fibers released tend to re-clump or adhere to pieces of fiber present downstream.
- No credit was taken for the above.

The results for Nukon erosion testing do not require extrapolation because 30 day tests were performed.

- The default assumption of 10 microns for unqualified coatings was not assumed for coatings based on analysis and testing described in Section 3.h.

According to Thermal Ceramics, Inc, Min-K fails as 20% fiber fines and 80% particulate fines. Data provided by Microtherm was used to develop specific fiber density for Min-K. This fiber density is consistent with the characteristic densities of fiberglass material. Based on SEM analysis of the Min-K present at Comanche Peak [Ref. 7.A.10], the fiber has an average fiber diameter of 5 bm and the particulate has an average particle diameter of 29.8 bm. This particle diameter is significantly different than that quoted in the NEI document NEI 04-07. The NEI document quotes a value such as 0.1 to 0.2 micron for a particle diameter. In actuality when referring to the MSDS sheets for the material that NEI quotes for Min-K, this measurement is actually the mean free space between the Min-K particles and hence the air space length between Min-K amorphous tufts. This is a significant aberration from an actual particle measurement, and as such the NEI quoted value for Min-K is not used for the characteristics of Min-K material.

3.e.3 Bounding LOCA Debris Located at the Sump

The post-LOCA debris located at the sump strainer was computed based on the quantity determined to be destroyed and transported. Note that although debris transports to the proximity of the strainer, it does not necessarily mean that it will accumulate on the strainer.

The calculation analyzed nine separate cases shown to determine the amount of debris that transports to Sump A and Sump B.

Case 1A – Loop 1 RCS Crossover Leg
Case 1B – Loop 1 RCS Cold Leg
Case 1C – Loop 1 RCS Hot Leg
Case 2 – Loop 2 RCS Main Loop Piping
Case 3 – Loop 3 RCS Main Loop Piping
Case 4A – Loop 4 RCS Crossover Leg
Case 4B – Loop 4 RCS Cold Leg
Case 4C – Loop 4 RCS Hot Leg
Case 4D – Pressurizer Surge Line Break in Loop 4 Compartment

These cases are shown on Figure 3.e.1.2-2 along with the cases for secondary line breaks. Features that were significant to transport were modeled (see Figures 3.e.1.2-3 and 3.e.1.2-4).

Each case was evaluated for Single Train (Sump A and Sump B) and two train (to Sump A and to Sump B). Therefore 4 transport cases were calculated for each of the nine cases above. The bounding debris load was conservatively determined for each sump by comparing all break locations and using the maximum amount transported for each debris type. See Figures 3.e.1.2-5 and 3.e.1.2-6 for selected figures from the transport analysis.

In general, a break in the Loop 4 main piping (hot leg, cold leg, or cross over leg) generates the largest quantity of RMI, fiberglass, and qualified coatings at each sump for single train or two train operation. However, for the single train operation, the Loop 1 cold leg break generates the largest amount of lead blanket cover fiberglass fines, lead blanket cover fiberglass large pieces and lead blanket lead wool fines at the sumps. The maximum Min-K transported to each sump is from the surge line break in the Loop 4 compartment.

For the two train operation, the maximum transport of large pieces of fiberglass to Sump A occurs from a break in the Loop 2 main loop piping. The Loop 1 cold leg break generates the largest amount of lead blanket cover fiberglass fines, lead blanket cover fiberglass large pieces and the lead blanket lead wool fines at the sumps. The maximum Min-K transported to each sump is from the surge line break in the Loop 4 compartment and the maximum amount of acceptable inorganic zinc (IOZ) coating is transported from the Loop 3 main pipe break. The maximum unqualified curled epoxy transported to Sump B is from the Loop 2 or Loop 3 main pipe break and the maximum amount of hot tar tubing is transported to Sump B from the Loop 2 or Loop 3 main pipe break.

To determine an overall bounding case, bounding single train cases and bounding two train case were compared and the overall bounding debris load is shown in Table 5-35. The single train operation is limiting for most debris types however, two train operation is more limiting for the RMI, larger fiberglass debris, and lead wool.

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An additional CFD case for Loop 4 SBLOCA Single Train – Sump A at minimum specified ECCS switchover was run. This run had the following configuration:

- A break in the Loop 4 Hot Leg
- A specified water level of 2 feet
- Sump A running at 1,200 gpm
- No spray flow
- A break flow rate of 1,200 gpm
- A pool temperature of 250F

The CFD results for this scenario show that essentially no debris would transport with the exception of very fine debris.

Because Comanche Peak does not have safety grade fan coolers for containment heat removal, the design and licensing basis is for containment spray actuation for the entire spectrum of LOCAs. A minimum of 2 feet of water for SBLOCA was selected for strainer design and transport analysis prior to modifications to increase water levels. The minimum flood level at ECCS switchover for small break LOCA has been conservatively calculated to be 2.56 feet. [Ref. 7.F.17]

The approach velocities to the strainer for SBLOCA at 2.56 feet and 1200 gpm would be very low (0.0014 fps versus 0.0074 fps at maximum design flow). Clean strainer head loss would be significantly reduced at such low flow. Best estimate analyses of a 2 inch RCS line break show that spray actuation would occur before ECCS switchover for 2 inch line breaks [Ref. 7.F.40]. The maximum ECCS recirculation flow for one sump for a 2 inch break would be approximately 400 gpm which is 8% of the maximum ECCS recirculation flow per sump of 4,900 gpm.

Therefore, it was concluded that debris generation and transport for SBLOCA conditions are well bounded by large break LOCA.

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<u>CONSERVATISM</u> - No settling of latent debris in the recirculation pool was credited. Although a much larger fraction of debris would likely be washed to the inactive reactor cavity during pool fill, the transport fraction was conservatively limited to 15% of that not blown into the upper containment in accordance

with the SE.

Based on the volume of the ECCS sump pits and the pool volume at the time when these cavities would fill, 9% of the latent debris not blown into the upper containment was also determined to transport to each sump during the pool fill phase.

The transport fraction for the latent debris in two train cases was determined to be 42% to Sump A and 45% to Sump B (87% overall transport). In the single train operation cases, 80% of the latent debris was determined to transport to either Sump A or Sump B depending on which train is active. The remaining 20% (i.e., 85% x (9% + 15%)) was debris that transported either to the reactor cavity or the inactive emergency sump.

The bounding debris load for LOCA by debris type is provided below.

Bounding Debris Load for All LOCA Conditions [Ref. 7.A.5]				
Debris Type	Bounding Debris Load	Transport Fraction	Bounding Operating Condition	Bounding Break Location
RMI Small Pieces	11268.82 ft^2	0.29	Two Train Sump A	Loop 4 Main Piping
RMI Large Pieces	2072.32 ft^2	0.16	Two Train Sump A	Loop 4 Main Piping
Anti-sweat Fiberglass Fines (@ 4.9 lb/ft3)	6.66 ft^3 32.63 lbs	0.93	Single Train Sump A or B	Loop 4 Main Piping
Anti-sweat Fiberglass Small (@ 4.9 lb/ft3)	22.63 ft^3 110.89 lbs	0.78	Single Train Sump B	Loop 4 Main Piping
Anti-sweat Fiberglass Large (@ 4.9 lb/ft3)	2.28 ft^3 11.17 lbs	0.17	Two Train Sump A	Surge Line Break in Loop 4 Compartment
Anti-sweat Fiberglass Jacketed (@ 4.9 lb/ft3)	2.30 ft^3 11.27 lbs	0.16	Two Train Sump A	Surge Line Break in Loop 4 Compartment
Lead Blanket Covers Fiberglass Fines	0.34 ft^3 26.84 lbs	0.93	Single Train Sump A or B	Loop 1 Cold Leg
Lead Blanket Covers Fiberglass Large	0.00384 ft^3 0.306 lbs	0.16	Two Train Sump A	Loop 1 Cold Leg
Lead Blanket Lead Wool Fines	0.215 ft^3 25.84 lbs	0.29	Two Train Sump A	Loop 1 Cold Leg
Min-K Fines (Fibrous portion)	0.10 ft^3 1.6 lbs	0.93	Single Train Sump A or B	Surge Line Break in Loop 4 Compartment
Min-K Fines (Particulate portion)	0.42 ft^3 6.72 lbs	0.93	Single Train Sump A or B	Surge Line Break in Loop 4 Compartment
Acceptable Epoxy (inside ZOI)	262.91 lbs	0.93	Single Train Sump A or B	Loop 4 Main Piping
Acceptable Inorganic Zinc (inside ZOI)	376.00 lbs	0.93	Single Train Sump A or B	Loop 4 Main Piping
Unqualified Epoxy (outside ZOI) Fines (6mil)	2838.02 lbs	1.0	Single Train Sump A or B	Loop 4 Main Piping
Unqualified Epoxy (outside ZOI) Fines (1/64")	2383.94 lbs	0.28	Two Train Sump A	Loop 4 Main Piping
Unqualified Epoxy (outside ZOI)	223.95 lbs	0.07	Two Train Sump A	Loop 4 Main Piping

Bounding Debris Load for All LOCA Conditions [Ref. 7.A.5]				
Debris Type	Bounding Debris Load	Transport Fraction	Bounding Operating Condition	Bounding Break Location
Small(1/8"-1/4",1/4"-½", 1/2"-1")				
Unqualified Epoxy (outside ZOI) Large(1"-2")	0.00 lbs	0.00	No transport	No transport
Unqualified Epoxy (outside ZOI) Curled (1/2"-2")	2352.98 lbs	0.50	Single Train Sump B	Loop4MainPiping
Unqualified Inorganic zinc (outside ZOI)	16834.2 lbs	1.00	Single Train Sump A or B	Loop 4 Main Piping
Unqualified Alkyd (outside ZOI)	103.67 lbs	1.00	Single Train Sump A or B	Loop 4 Main Piping
Dirt/Dust	136.00 lbs	0.80	Single Train Sump A or B	Loop 4 Main Piping
Latent Fiber	10.00 ft^3	0.80	Single Train Sump A or B	Loop 4 Main Piping
Unqualified Labels	200.00 ft^2	1.00	Single Train Sump A or B	Loop 4 Main Piping
Tape	5.00 ft^2	1.00	Single Train Sump A or B	Loop 4 Main Piping
Electromark Labels - Clear Outer Laminate Layer	1229.00 ft^2	1.00	Single Train Sump A or B	Loop 4 Main Piping
Electromark Labels - Sub-Layer	1229.00 ft^2	1.00	Single Train Sump A or B	Loop 4 Main Piping
Potable Water Tubing	0.075 ft^3	0.85	Single Train Sump A or B	Loop 4 Main Piping
Hot Tar Tubing	0.31 ft^3	0.85	Single Train Sump A or B	Loop 4 Main Piping

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3.e.4 MSLB Debris Located at the Sump

The calculated debris transport fractions and total quantities of each type of debris assumed to be transported to the strainers for MSLB is also documented in ALION-CAL-TXU-2803-06, Summary of Debris Generation and Debris Transport Results [Ref. 7.A.5].

Secondary line breaks differ from LOCAs in that the entire content of the RWST is injected into containment before the start of recirculation. With a minimum useable volume of 440,300 gallons [Ref. 7.F.41] and a maximum injection rate of 15,200 gpm, there would be a minimum of 29 minutes for wash down and settling of debris. Break flow would terminate once the faulted steam generator completes blow down. The function of the CSS to limit containment pressure and temperatures is a short term function which primarily occurs during injection. Recirculation is primarily for the longer term cool down to return to ambient conditions.

The containment cross sectional area is 14314 ft^2. The spray flow of 5440 gpm from one train of CSS at the top floor elevation (El 905'-6") would be 0.7 inches per minute. Wash down of Elevation 860 (floor area 6257 ft^2) from one train of CSS at 1340 gpm (207 ft^3/min) would be 0.4 inches per minute equivalent to a 24 inch per hour rainfall. Wash down of debris would be expected to be complete well before start of recirculation. Clean water entering the pool following wash down would push the settled debris away from the turbulent areas where fibrous debris would naturally tend to agglomerate. Settling of the particulate debris would further tend to weigh down the settled fibers and retard transport. The primary transport mechanism to the sump in recirculation would be by tumbling which is mitigated by the debris interceptor around the strainer. Regardless, these physical phenomena were not credited in the transport analysis. The same conservative transport analysis as was used for LOCA was used for secondary line breaks.

The bounding debris load was conservatively calculated using the same methodology for transport as for LOCA except the MSLB transport only evaluated maximum two train transport. The bounding debris load is the total for both sumps.

Bounding Operating Condition - Two Train Sump A and B. The debris load is the total for both sumps.

Bounding Break Location - MSL Penetration Area

A comparison to the prototype testing [Ref. 8.D.2] is made below.

Bounding Debris Load for MSLB Conditions [Ref. 7.A.5]				
Debris Type	Bounding Debris Load	Transport Fraction	Prototype Test Debris Load [Ref. 8.D.2]	Bounded by prototype test
RMI Small Pieces	3044.80 ft^2	0.44	12318 ft^2	Yes
RMI Large Pieces	0.00 ft^2	0.00	0.00 ft^2	N/A
Anti-sweat Fiberglass Fines (@ 4.9 lb/ft3)	8.69 ft^3 42.6 lbs	1.00	98.3 ft^3 @ 5.5 lb/ft^3 540.65 lbs	Yes
Anti-sweat Fiberglass Small (@ 4.9 lb/ft3)	32.67 ft^3 160.0 lbs	0.94		
Anti-sweat Fiberglass Large (@ 4.9 lb/ft3)	0.00 ft^3 lbs	0.01	0.00 ft^3	N/A
Anti-sweat Fiberglass Jacketed (@ 4.9 lb/ft3)	0.00 ft^3 lbs	0.00	0.00 ft^3	N/A
Kaowool	44.2 ft^3 353.6 lbs	1.00	56.1 ft^3 448.8 lbs	Yes
Sil-temp	0.88 ft^3 52.4 lbs	1.00	1.2 ft^3 71.4 lbs	Yes
Min-K Fines (Fibrous portion)	0.81 ft^3 12.96 lbs	1.00	0.5 ft^3 30 lbs	Yes
Min-K Fines (Particulate portion)	3.26 ft^3 52.16 lbs	1.00	34.3 lbs	No
Acceptable Epoxy (inside ZOI)	217.5 lbs	1.00	3860.9 lbs	Yes
Acceptable Inorganic zinc (inside ZOI)	366.9 lbs	1.00	267.5 lbs	No
Unqualified Epoxy (outside ZOI) Fines (6 mil)	2838.02 lbs	1.0	12920 lbs as particulate fines (walnut shells)	Yes. Note 12920 lbs as paint chips were tested under bounding LOCA conditions with no fiber.
Unqualified Epoxy (outside ZOI) Fines (1/64")	0.00 lbs	0.00		
Unqualified Epoxy (outside ZOI) Small(1/8"-1/4",1/4"-½", 1/2"-1")	0.00 lbs	0.00		
Unqualified Epoxy (outside ZOI) Large(1"-2")	0.00 lbs	0.00		
Unqualified Epoxy (outside ZOI) Curled (1/2"-2")	4705.95 lbs	1.00		

Bounding Debris Load for MSLB Conditions [Ref. 7.A.5]				
Debris Type	Bounding Debris Load	Transport Fraction	Prototype Test Debris Load [Ref. 8.D.2]	Bounded by prototype test
Unqualified Inorganic zinc (outside ZOI)	16834.2 lbs	1.00	25634 lbs	Yes
Unqualified Alkyd (outside ZOI)	103.67 lbs	1.00	992 lbs	Yes
Dirt/Dust	136.00 lbs	0.80	170 lbs	Yes
Latent Fiber	10.00 ft^3	0.80	12.5 ft^3	Yes
Unqualified Labels	200.00 ft^2	1.00	N/A	Sacrificial Area
Tape	5.00 ft^2	1.00	N/A	Sacrificial Area
Electromark Labels - Clear Outer Laminate Layer	1229.00 ft^2	1.00	N/A	Bounded by LOCA Testing
Electromark Labels - Sub-Layer	1229.00 ft^2	1.00	N/A	Bounded by LOCA Testing

The above comparison shows that the prototype testing conservatively bounded the current debris generation and transport results for both fiber and particulate. To assess if the design basis LOCA testing debris load would bound the secondary line break, the following comparison was made.

Comparison of MSLB and LOCA Test Conditions [Ref. 8.D.2 and 8.D.9]

Debris Type	Bounding Debris Load	Prototype Test		LOCA Test	Bounded by LOCA testing
		MSLB	LOCA		
RMI Small Pieces	3044.80 ft^2	12318 ft^2	25387 ft^2	11268.82 ft^2	Yes
RMI Large Pieces	0.00 ft^2	0.00 ft^2	0.00 ft^2	2072.32 ft^2	Yes
Anti-sweat Fiberglass Fines	42.6 lbs	540.65 lbs	114.95 lbs	35.9 lbs	No (1) (3)
Anti-sweat Fiberglass Small	160.0 lbs			116.4 lbs	
Anti-sweat Fiberglass Large	0.00 ft^3	0.00 ft^3	0.00 ft^3	11.28 lbs	Yes
Anti-sweat Fiberglass Jacketed	0.00 ft^3	0.00 ft^3	0.00 ft^3	11.28 lbs	Yes
Kaowool	353.6 lbs	448.8 lbs	n/a	n/a	No (1)
Unqualified Inorganic zinc (outside ZOI)	16834 lbs	25634 lbs	25634 lbs	17062 lbs	Yes
Sil-temp	52.4 lbs	71.4 lbs	n/a	n/a	No
Min-K Fines (Fibrous portion)	12.96 lbs	30 lbs	30 lbs	3.4 lbs	Prototype
Min-K Fines (Particulate portion)	52.16 lbs	34.3 lbs	30.7 lbs	10.2 lbs	Yes (2)
Acceptable IOZ (inside ZOI)	366.9 lbs	267.5 lbs	342.3 lbs	376 lbs	
Unqualified IOZ (outside ZOI)	16834 lbs	25634 lbs	25634 lbs	17062 lbs	
Acceptable Epoxy (inside ZOI)	217.5 lbs	3860.9 lbs	4360.5 lbs	262.91 lbs	Yes
Unqualified Epoxy (outside ZOI) Fines (6 mil)	2838 lbs	12920 lbs as particulate fines (walnut shells)	12920 lbs as particulate fines (walnut shells)	2838 lbs	Yes
Unqualified Epoxy (outside ZOI) Fines (1/64")	0.00 lbs			2394 lbs	
Unqualified Epoxy (outside ZOI) Small	0.00 lbs			224 lbs	
Unqualified Epoxy (outside ZOI) Curled	4705.95 lbs			2353 lbs	
Unqualified Alkyd (outside ZOI)	103.67 lbs	992 lbs	992 lbs	103.67 lbs	Yes
Dirt/Dust	136.0 lbs	170 lbs	144.5 lbs	136.0 lbs	Yes
Latent Fiber	10.0 ft^3	12.5 ft^3	9.9 ft^3	10.0 ft^3	Yes

Note 1: Antisweat fiberglass, Kaowool and Sil-Temp debris is not generated by the current design and licensing basis main steam and feedwater (secondary) line breaks. Therefore, LOCA testing does bound the debris for design basis main steam and feedwater line breaks.

Note 2: The test surrogate for Inorganic Zinc both inside and outside the ZOI is conservative for both inorganic zinc (IOZ) and for Min-K particulate. Therefore, testing bounded both Min-K and IOZ.

Note 3: The MSLB testing conservatively applied 100% of the two train debris load on the prototype for one strainer. In a prototypical test, the debris would have been reduced to 50% to 60% to account for debris split between trains. In one train operation, the transport flow would be half of that for two train operation resulting in significantly reduced debris. Given this consideration, the design basis LOCA fiberglass test debris bounds the MSLB fiberglass debris.

Although the prototype testing in the small flume [Ref. 8.D.1, 8.D.2, and 8.D.3] was done prior to the March 2008 NRC guidance on testing, it provides valid data to compare that test to the design basis test in the large flume [Ref. 8.D.8 and 8.D.9] and evaluate the sump performance.

The NRC witnessed portions of the small flume prototype testing and noted that CPSES had addressed several issues the staff had raised during its previous visits to observe testing. Documentation of those issues are included in the trip report [Ref. 1.M].

<u>CONSERVATISM</u> - Prototype testing was done with an ultra-conservative test temperature below 50 degrees F. Fiberglass fibers settle in 20 to 60 minutes in 50 °F water versus 20 to 30 seconds in 120 °F water [Ref. 9.Q, NUREG/CR-2982, "...water temperature has a paramount effect on buoyancy..."]. Tests conducted at 128 °F and 169 °F confirmed the effect on settling of fiberglass [Ref. 15.A, Test Report No. ITR-92-03N]. This is a significant conservatism in the prototype test because the fine fibrous debris is mixed at and around the test module at the beginning of flow and the suspended fibers did not settle as they would in a prototypical event.

The only MSLB debris type not bounded by the prototype LOCA test and the design basis LOCA test was the Kaowool and Sil-temp. These debris materials are not within the ZOI for LOCA or design basis Main Steam and Feedwater Line Breaks. A very small quantity of these materials are located in the vicinity of the steam generator blow down lines; however, these small breaks would be well bounded by LOCA breaks.

The NRC witnessed Comanche Peak prototype testing and documented observations in trip report "Staff Observations Regarding Flume Testing of a Prototype Portion of the Proposed Replacement Suction Screen Design for the Comanche Peak Steam Electric Station (DOCKET NOS. 50-445 AND 50-446)" dated June 30, 2006 [ADAMS Accession # ML061710147]. It was noted that testing issues that the NRC had raised in earlier tests had been addressed.

The only notable protocol difference between the prototype MSLB and LOCA tests was the flow rate (approach velocity). Although the MSLB test had substantially more fiber, the head loss was negligible.

The test results were as follows:

- MSLB Head Loss – Small Flume 0.005 ft. (0.0044 fps)

- LOCA Head Loss – Small Flume 0.4682 ft. (0.0073 fps)
- LOCA Head Loss – Large Flume 0.6 ft. (0.0073 fps)

A comparison of the prototype LOCA testing to the design basis LOCA testing in the large flume shows that the new protocol is bounding although this is partially due to the included chemical precipitates. However, the results are still comparable. The prototype MSLB test was overwhelmingly bounded by the prototype LOCA test in the same flume with the same protocol. It is reasonable to conclude that the Prototype testing demonstrated that LOCA conditions of debris and strainer approach velocity bound the postulated MSLB conditions for sump performance for fibrous and particulate debris.

The prototype testing did not include chemical precipitates that met the current acceptance criteria. Cooldown from a secondary line break is rapid in comparison to LOCA giving little time at high temperatures which accelerate chemical reactions. The CSS mission time for secondary line breaks is less than 10 hours. It is reasonable to assume that chemical precipitates would be insignificant in comparison to the large particulate conservatism in the MSLB prototype test and would be well bounded by the LOCA testing.

Based on the prototype testing and the arguments above, it was concluded that LOCA testing with chemicals would bound MSLB with chemicals and that testing for MSLB debris with chemicals would not be required.

Section 3.f Head Loss and Vortexing

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

Head loss and vortex formation were evaluated by a combination of testing and analysis:

Prototype Test -	AREVA NP, Engineering Information Record, Document Identifier 519024342-001, Comanche Peak 1 & 2 Strainer Performance Test Report [Ref. 8.D.2]
Test Plan -	AREVA NP Document No. 63-9073071-001, Test Plan [Ref. 8.D.6]
Qualification Test -	EC-PCI-CP-6004-1005, AREVA NP Document No. 66-9078989-000 "Comanche Peak Test Report for ECCS Strainer Performance Testing.[Ref. 8.D.9]
Clean Strainer Head Loss -	TDI-6004-05, Clean Head Loss Comanche Peak Steam Electric Station [Ref. 8.B.6]
Head Loss -	TDI-6004-06, Total Head Loss Comanche Peak Steam Electric Station [Ref. 8.B.7] Note: The NUREG/CR-6224 head loss analysis for CPSES based on the conservative debris source term was inconclusive. The debris source term produces conditions that are outside the range of applicability of the NUREG/CR-6224 correlation [Ref. 7.A.4]. Strainer head loss is based on strainer testing data.
Vortexing -	TDI-6004-07, Vortex, Air Ingestion & Void Fraction - Comanche Peak Steam Electric Station [Ref. 8.B.8]

3.f.1 Description of the Emergency Core Cooling System and Containment Spray System

The Emergency Core Cooling System is described in FSAR [Ref. 2.B] Section 6.3. The system flow diagram is Figure 6.3-1. A simplified schematic is shown on Figure 6.3-1.

The Containment Spray System is described in the FSAR [Ref. 2.B] Section 6.2.2. The system flow diagram is Figure 6.2.2-1.

CPNPP contracted with Performance Contracting, Inc. (PCI) to provide a qualified Sure-Flow® Suction Strainer specifically designed for CPNPP in order to address and resolve the NRC GSI-191 ECCS sump perfomance issue. (See Section 3.j for details)

The minimum calculated flood levels for the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions is given in Ref. 7.F.17. The calculated flood levels are higher than the originally specified flood levels. Secondary Line Breaks (e.g. MSLB) are bounded by SBLOCA. (See Section 3.g for details). The top of the strainer is 45 inches above floor Elevation 808'-0".

	Specified Minimum Flood Levels	Calculated Minimum Flood Levels	Submergence
SBLOCA Minimum Sump Water Level at start of CSS recirculation	El. 812.3 ft (4.3 ft. above the 808' floor elevation)	El. 812.55 ft (4.55 ft. above the 808' floor elevation)	>/= 0.80 ft (Note 1)
LBLOCA Minimum Sump Water Level at start of CSS recirculation	El. 813.0 ft (5.0 ft. above the 808' floor elevation)	El. 813.21 ft (5.21 ft. above the 808' floor elevation)	>/= 1.46 ft

Note 1: SBLOCA bounds MSLB in both flow (higher) and submergence (lower)

The USNRC in RG 1.82 Revision 3 [Ref. 9.G], specifically Table A-6 provided guidance with regard to vortex suppressors. The table specifies that standard 1.5" or deeper floor grating or its equivalent has the capability to suppress the formation of a vortex with at least 6" of submergence. The design configuration of the PCI Sure-Flow® suction strainer for CPNPP due to the close spacing of various strainer components and the small hole size of the perforated plate meets and/or exceeds the guidance found in Table A-6. The CPNPP strainer meets the 6" submergence requirement at the beginning of full sump recirculation flow.

Because CPNPP is a low fiber plant and LDFG settling increases with temperature, there is little potential for floating debris. The minimum submergence should be more than adequate to assure buoyant debris will not cause formation of an air flow path to the strainer surface. There was a considerable quantity of floating LDFG in Test 5 during prototype testing (photo on page 7 in Attachment B) and no air ingestion was observed.

Although the strainers are fully submerged prior to initiation of full flow, they are only partially submerged at the start of ECCS switchover. For this reason, the core tube in the PCI Sure-Flow® suction strainer for CPNPP was designed with a maximum height of 2.0 ft above the floor so that it would always be fully submerged at the start of flow through the strainer. This partial flow is approximately 40% of full flow.

RAI 13 The minimum water level at ECCS switchover for Large Break LOCA is El. 811.12 which is 3.12 feet above the floor (see Section 3.g). The flood level would be less than 8 inches from the top of the 45 inch tall strainers. The ECCS flow rate would be from 4900 gpm (40% of design flow). This is a transient operating condition since containment spray will continue to inject RWST water over a maximum of 25 minutes at which time the minimum submergence in the table above is achieved and full sump flow begins. Water level would be rising at greater than 1.2 inches per minute. Therefore, the period of time the strainers are not fully submerged with partial flow is very short (i.e., the strainer will be fully submerged in less than 7 minutes). This transient was tested with debris during prototype testing [Ref. 8.D.2]. Although the full debris load was present at the start of the test, no head loss was observed during the flood up with the partial flow. See Attachment B for selected pictures of the prototype testing including the flood up test..

RAI 22 The minimum water level at ECCS switchover for Small Break LOCA is El. 810.56' which is 2.56 feet above the floor (see Section 3.g). The flood level would be less than 15 inches from the top of the 45 inch tall strainers. The ECCS flow rate would be from 400 to 1200 gpm (10% of design flow). This is a transient operating condition since containment spray will automatically start before ECCS switchover and will continue to inject RWST water over a maximum of 25 minutes at which time the minimum submergence in the table above is achieved and full sump flow begins. Water level would be rising at greater than 1.2 inches per minute. Therefore, the period of time the strainers are not fully submerged with partial flow is very short (i.e., the strainer will be fully submerged in less than 13 minutes). Because LOCA debris generation and transport would be bounding, separate transient testing was not performed.

3.f.2 Design Basis Debris Load

Maximum Debris Loads for Testing [Ref. 8.A.1]

Debris Type	LOCA
Latent Fiber (cu. ft.)	10
Latent Particulate (lbm)	136
Low Density Fiberglass (cu. ft.)	69.2 (@ 2.4 lbm/ft3)
Fines	13.6
Small	46.2
Large	4.7
Jacketed	4.7
Lead Blanket Covers	
Fines [lbm]	33.14
Large [lbm]	0.38
Lead Wool	
lbm	25.84
(cu. ft.)	0.215
Min-K (lbm) (0.52 cu.ft.@ 16 lbm/ft3)	8.33
RMI (sq. ft.).	13,341.14 (below)
Small pieces	11,268.82
Large pieces	2072.32

Maximum Debris Loads for Testing [Ref. 8.A.1]

Debris Type	LOCA
Coatings - ZOI (lbm)	638.9 (below)
High Build Epoxy	0
Epoxy	262.91
Inorganic Zinc	376
Silicone	0
Coatings - Zinc (lbm)	17,062.2
Coatings - Epoxy (lbm)	7,798.87 (below)
Fines (6 mils)	2838
Fines (1/64 in.)	2393.94
Small (>1/8 in.)	223.95
Large curled (>½ in.)	2352.98
Coatings - Alkyd Enamel (lbm)	103.67
Chemical Byproducts (lbm)	243.7 (59 ppm)
NaAlSi3O8 Precipitate	173.2 (42 ppm)
AlOOH Precipitate	70.5 (17 ppm)
Labels and tags	1229 ft^2 Electromark Series 1000 plus 200 ft^2 sacrificial area (misc debris)
Neoprene Oil Collection tubing (cu.ft.)	0.075
Hot tar oil collection tubing (cu.ft.)	0.31

3.f.3 Strainer Qualification Testing

Pictures of the Alden test facility and testing are provided in Attachment D.

3.f.3.1 Methodology and Assumptions

The basic test methodology was to test a full size strainer in a prototypical configuration which included a full height debris interceptor. The test facility conservatively modeled the near field transport conditions based CFD models used for debris transport. This test method is appropriate for the PCI Sure-Flow® suction strainer for CPNPP because of the flow control features which assure that each strainer module will draw from the recirculation pool at approximately equal flow rates.

Actual plant materials were prepared and used for testing when practical. When that was not practical, a suitable surrogate was selected which provided similar or conservative test results.

NUKON is assumed to be an adequate surrogate for CPNPP low density fiberglass. Heat treating is not required to remove the binder to simulate in-service conditions. Processing dry NUKON through a chipper (e.g leaf shredder) and then through a shredder (e.g. food blender) produces an appropriate surrogate for fines. Mixing the fines in a container prior to introduction in the test flume with water using a mechanical paddle mixer (or similar type device) assures that there are no clumps of fiber.

For coatings, surrogates of similar size, shape, and density are assumed to be adequately conservative for testing. Tin powder is an appropriate surrogate for inorganic zinc. Crushed and ground acrylic paint powder is an appropriate surrogate for coatings in the zone of influence. Acrylic or epoxy chips can be manufactured in a range of specific gravity and sizes to be an appropriate surrogate for epoxy chips.

RAI 34 Treatment of chemical effects conformed to WCAP-16530-NP Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191 [Ref. 6.B] with further clarification from the PWROG.

<u>CONSERVATISM</u> - Conservatisms were identified in the generic chemical model which could be addressed through the inclusion of more plant-specific inputs. However, the refinements in WCAP-16785-NP Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model [Ref. 6.C] were not used.

Generated chemical precipitates were used to simulate chemical effects. Specifically, chemical precipitates were generated and verified at ARL per the WCAP methodology.

CONSERVATISM - Although Sodium Aluminum Silicate (NaAlSi3O8) makes up 83% of the precipitate, Aluminum Oxyhydroxide (AlOOH), which causes higher head losses, was used as the surrogate for testing.

Chemical material was generated in mixing tanks and introduced into the test flume within the parameters provided in PWROG letter OG-07-270, New Settling Rate Criteria for Particulates Generated in Accordance with WCAP-16530-NP (PA-SEE-0275) [Reference 6.G] and PWROG letter OG-07-408, Responses to NRC Requests for Clarification Regarding WCAP-16530, "Evaluation of Chemical Effects in Containment Sump Fluids to Support GSI-191" (PA-SEE-0275) [Ref. 6.H]. This requirement was in accordance with findings that some of the generated chemical precipitants deteriorate after initial generation.

AlOOH precipitates generated were introduced within 24 hours of their generation/acceptance for use.

Because the test facility is in Massachusetts, the protocol included warming the water in the test flume to more prototypical conditions for CPNPP.

Debris Preparation and Surrogates

RAI 8, 25 Debris Preparation and the selection of test surrogates were in accordance with SFSS-TD-2007-004, Testing Debris Preparation and Surrogates and SSFS-TD-2007-004 Sure-Flow® Suction Strainer - Testing Debris Preparation and Surrogates, Supplement 1, Revision 1 [Ref. 8.D.4].

PCI processed raw fibrous debris materials into 'fines' representative of either eroded or latent fibrous debris and 'fines/smalls' by recognized mechanical process devices (i.e., chipper (smalls) & Munson machine (fines)). PCI separated (i.e., size distribution) the processed fibrous debris utilizing a 1' x 4" grating opening which is more conservative than the 4" x 4" grating opening identified in NEI 04-07 and the Staff's SE for the same. Sample of latent, fines/smalls, and larges were provided to the Staff before any Large Flume Testing was initiated and were found to be representative of what the Staff had expected.

CONSERVATISM - Fiber debris preparation resulted in smalls used in Comanche Peak testing being comprised of up to 41% fines.

CONSERVATISM - Large Fiber Debris is defined by PCI as fibrous debris that WILL NOT pass through a 1" x 4" opening in a dry form. Per NEI 04-07, the opening size through which fibrous debris classified as 'large' fibers do not pass is 4" x 4". Therefore, PCI is using a much more conservative criteria for the 'large' fiber classification. Large fibrous debris is processed using a "wood chipper". The capture method of collecting not only 'large' fibrous debris clumps but also the 'small / fine' fibrous debris discharged by the wood chipper results in some percentage of fines being included in the large debris.

CONSERVATISM - Intact blankets were prepared as Large Fiber debris for the Comanche Peak testing.

The tests were performed with the quantities of debris stated in 3.f.2 scaled for the test strainer. The debris mixes for each test were weighed dry and prepared in buckets and/or large trash cans by mixing the debris with water using a paint mixer powered by an electric drill for particulate debris and fine fibrous debris and by hand for the other debris types.

The CPNPP debris allocation [Ref. 8.D.5] provided the design inputs for the test plan.

Debris Type	Surrogate
Latent Fiber	NUKON thru debris shredder
Latent Particulate	PCI - PWR Mix 1 [Ref. 8.D.4]
Low Density Fiberglass	
Fines	NUKON dry shredded thru debris shredder
Small	NUKON dry shredded thru debris chipper and passed thru a 1" x 4" grid
Large	NUKON dry shredded thru debris chipper and not passed thru a 1" x 4" grid
Jacketed	NUKON dry shredded thru debris chipper and not passed thru a 1" x 4" grid
Lead Blanket Covers	
Fines	Blanket covers dry shredded thru debris chipper
Large [lbm]	6"x 6" pieces

Debris Type	Surrogate
Lead Wool	Stainless Steel wool
Min-K	Min-K
RMI	
Small pieces	½", 1", and 2" square pieces
Large pieces	4" x 6" square pieces
Coatings - ZOI	
High Build Epoxy	Acrylic powder
Epoxy	Acrylic powder
Inorganic Zinc	Tin powder
Silicone	Acrylic powder
Coatings - Zinc	Tin Powder
Coatings - Epoxy	
Fines (6 mils)	Epoxy chips
Fines (1/64 in.)	Epoxy chips
Small (>1/8 in.)	Epoxy chips
Large curled (>½ in.)	Mylar chips
Coatings - Alkyd Enamel	Acrylic powder
Chemical Byproducts	
NaAlSi3O8 Precipitate	WCAP chemical surrogate AlOOH
AlOOH Precipitate	WCAP chemical surrogate AlOOH
Labels and tags	Boiled 15 to 20 miuntes
Neoprene Oil Collection tubing (cu.ft.)	2", 4", and 6" pieces
Hot tar oil collection tubing (cu.ft.)	2", 4", and 6" pieces

Debris Sequencing

The order of the debris sequencing into the flume varied depending on the test. All debris was introduced at the upstream end of the test flume while the recirculation pump was running with the exception of latent fiber in Test 4. For headloss testing, except for latent fiber, the fine particulate debris was introduced prior to the fine fibrous debris. See Section 3.f.3.3 below.

Termination Criteria

Termination criteria for head loss testing was based on flume pool turnovers, rate of head loss change, and head loss extrapolation. Termination criteria was achieved with a minimum of 15 pool turnovers and a head loss change of less than 1% in 30 minutes. Linear extrapolation of the raw data for 30 days showed that the test results were sufficient to support head loss analysis.

3.f.3.2 Test Facility

Comanche Peak supplied a prototype strainer consisting of a spare strainer module for the tests. Alden personnel provided the test facility and performed the test at the Alden facility. The test apparatus included a test flume, two pumps, the spare strainer, instrumentation & controls, and associated piping and valves needed to complete a recirculation loop with the pumps in a parallel setup, a chemical mixing tank, a pump designated to pump the chemical debris into the test flume, and associated piping/tubing. Water in the flume was displaced as debris and chemicals were added to the flume. To maintain a steady water level during testing, a removable 250 micron pre-screen was used upstream of an over flow pipe set at the proper water elevation. Debris which penetrated the 250 micron pre-screen either flowed into the over flow pipe or remained captured within the "pre-screen compartment" area. Debris which flowed into the over flow pipe was further filtered and captured by the 10 micron bag filters located downstream of the over flow pipe. The debris captured by the bag filters was flushed periodically to return the captured debris back into the test flume. Each time this task was performed the removable 250 micron screen was also removed to allow the debris captured therein to return back to the flume.

The test apparatus consisted of a steel flume measuring 10 feet wide, 5 feet deep, and 45 feet long. Inside of the steel flume, plywood was used to contour the flume walls to simulate the containment approach velocities. The upstream most portion of the flume was used to introduce the flow into the flume resulting in a 27' 4 13/16" long test section. The flume was equipped with two flow systems designated as the Strainer Flow Loop and as the Heat Recirculation Loop. To reduce the hydrostatic forces on the plywood walls and eliminate the leaking which was observed prior to the first test, water was added on both sides of the flume testing section at the same water level.

The test strainer module has a surface area of 109.5 ft2 when fully submerged and is identical to those modules installed in the Comanche Peak containment buildings. It should be noted that the test conditions (flow-rate and debris quantities) were scaled down based on the surface of the strainer module adjusted for the sacrificial surface area (see Section 3.j).

Testing Parameters

Module Surface Area = 109.5 ft2
Scaling Factor for test parameters = Test module area of 109.5 ft^2/(total surface area of 3947 ft^2 - sacrificial area of 200 ft^2) = 0.02922 (2.922%)
Flow through SFS Module = 12, 420 gpm x 2.922% = 363 gpm
Velocity through SFS Module = 0.0074 ft/sec
Velocity through Test Flume = Varies as described below

Approach velocities to the test strainer module, used to configure the flume walls, were determined using a localized CFD model.

The calculation of the Comanche Peak Sure Flow Strainer qualification test program flume configuration utilizes the results of the Alion CFD debris transport study [Ref. 7.A.3] as well as the approach flow velocity planes defined by Alion in Ref. 7.A.18 to define the weighted average approach velocities to each strainer array. Approach velocities to the test strainer module, used to configure the flume walls, were determined using a localized CFD model by calculating average velocities at incremental distances away from the end of the strainers.

The weighted average velocity to each strainer array was used by Alden/Areva to determine the weighted average velocity for the test flume. [Ref. 8.D.10]

Distance Back from the Strainer (ft)	WT AVG (2X Max)(ft/s)
1	0.467
4	0.406
7	0.536
10	0.548
22	0.617

These flume transport velocities are also conservative because they represent bounding transport prior to the first strainer module in each train. The ends of each strainer array are protected by a solid debris diverter which make all debris go around and approach the strainers at a right angle to the predominant flow. Figures 3.f-1 and 3.f-2 in Attachment E show the CFD cutting planes for each strainer. See Section 3.e for a description of the CFD results. The dimension of the flume were determined based on the weighted average velocities above and a test water depth of 50 inches (4.17 ft).

RAI 10, 11 A CFD comparison of the debris transport model to the test flume was performed and presented to the NRC. See Attachment F [Ref. 1.L]. This comparison shows that the use of the two train CFD flow rates to model the flume offsets the turbulence from flow out of loop room 1 upstream of train A.

RAI 13 <u>NOTE</u>: Conservative transient flood up testing was performed during prototype testing [Ref. 8.D.1 and 8.D.2] and was not repeated.

RAI 16 The transition of the flume near the test strainer module is defined by the trajectory of the water as it approaches the modules in the prototype installation. These flow patterns are calculated in the CFD debris transport analysis. Engineering judgment was used to interpret these flow patterns and define the shape of the flume at the test module. As described in Section 3.e.1.2, the flow to the first strainer module, which was modeled in the testing, must make a sharp turn of approximately 90 degrees immediately in front of the debris interceptor.

<u>CONSERVATISM</u> - The transport over the debris interceptor was 0.18 fps in the head loss test flume as opposed to 0.12 fps in the plant.

Head loss and bypass tests were conducted with city domestic (tap) water. Initially, the flume was filled with city water at ambient temperature. The water was heated to a temperature of ~120°F via the Heat Recirculation Loop. The Heat Recirculation Loop consists of a heat recirculation pump and an 800,000 BTU heat exchanger. The flume water was pumped via the heat recirculation pump into the 800,000 BTU heat exchanger. A secondary closed loop system consisting of a separate pump and a boiler, which supplied the heat input for this heat exchanger. Once the water temperature reached ~120°F, the boiler was shut down and the Heat Recirculation Loop was isolated via the valve downstream of the heat recirculation pump. Immersion heaters were used to keep the test flume water at elevated temperatures (>90°F).

RAI 14 <u>Debris Transport Test</u>

Some label testing where labels were placed directly on the strainer was done in the main flume;

however, debris transport testing was done in separate flumes.

Because the transport over the debris interceptor was 0.18 fps in the head loss test flume as opposed to 0.12 fps in the plant [Ref. 7.F.34], the main flume was considered overly conservative for testing miscellaneous items. The head loss flume was narrow and the testing could not be viewed from the sides. Therefore, two separate flumes were used to test labels, tape, etc. (e.g., debris that is counted against the sacrificial area) and RMI, hoses, etc. (e.g., tumbling debris that could not reach the strainer). The debris interceptor was replicated in both flume. The larger of these flumes tested at 0.2 fps and 0.5 fps The average transport velocity in front of the debris interceptor is 0.08 fps; therefore, a minimum of 0.1 fps was used for testing in the smaller flume.

The debris transport tests (both in the larger flume and the smaller flume) were performed at ambient temperature (~40°F to 60°F).

The debris transport testing conditions were conservative for the types of debris being tested.

3.f.3.3 Testing, Results and Conclusions

Strainer Qualification Tests

Four strainer qualification tests were performed during the testing period. The testing order and test descriptions are as follows:

1) **Test 1 – Clean Strainer Head Loss Test** – This test determined the head loss of the clean strainer which will be subtracted from the latter tests to determine the "debris-bed" head loss.

   The test strainer was evaluated using clean water to measure the clean strainer head loss over an operating range from approximately 200 gpm to 500 gpm. Five flow rates were tested. The head loss reading was taken downstream of the strainer which provided the pressure drops of both the clean strainer and the losses through a portion of the suction piping.

   No debris was introduced for this test. Testing was done conservatively with only 5 inches of submergence. No vortices were observed during testing.

2) **Test 2 – Fibrous Debris Only (No Particulate) Bypass and Head Loss Test** –

This test determined that a thin bed of fiber will not form on the strainer based on observations through the surface of the water as well as observations using an underwater camera as well as a the head loss of a "fiber" only condition. Note that debris bypass testing was performed during this test. See Section 3.m for bypass testing details.

For Test 2, fiber only test, the order for debris introduction was as follows:

- Batch 1: 0.10 lbm of Min-K (fine) debris, 1.05 lbm of LDFG (fine NUKON) debris, and 0.80 lbm of the Latent fibrous debris
- Batch 2: 1.70 lbm of LDFG (small NUKON) debris
- Batch 3: 1.70 lbm of LDFG (small NUKON) debris
- Batch 4: 1.05 lbm of Lead Blanket Covers (fines)
- Batch 5: 0.40 lbm of LDFG (large NUKON) debris and 0.40 lbm of LDFG (large intact) (large NUKON) debris

Testing was done conservatively with only 5 inches of submergence. No vortices were observed during testing.

3) **Test 3 – Particulate Debris Only (No Fibers) Bypass and Head Loss Test** – This test determined the head loss of a "particulate" only condition. Note that debris bypass testing was performed during this test. See Section 3.m for bypass testing details.

For Test 3, particulate only test, the order for debris introduction was as follows:

- Batch 1: 41.55 lbm of pulverized acrylic paint chips (6 mils)
- Batch 2: 41.55 lbm of pulverized acrylic paint chips (6 mils)

Testing was done conservatively with only 5 inches of submergence. No vortices were observed during testing.

4) **Test 4 – Design Basis Debris Loaded Strainer Head Loss Test** – This test was used to determine the debris bed head loss for the design basis accident. Note that debris bypass testing was performed during this test. The bypass samples were analyzed by NSL and will be evaluated by AREVA for bypass percentages which then can be applied in downstream evaluations.

RAI 27

For Test 4, design basis debris loaded head loss test, the debris types were introduced into the test flume separately. The order for debris introduction was as follows:

- Batch 1a: 0.50 lbm of the Latent fibrous debris placed uniformly in the test flume upstream of the debris interceptor prior to starting the recirculation pump.
- Batch 1: 10.80 lbm of pulverized acrylic paint chips, 4.05 lbm of particulate latent dirt and dust, 510.4 lbm of tin powder, 0.10 lbm of Min-K (fine) debris, 1.05 lbm of LDFG (fine NUKON) debris, and 0.30 lbm of the Latent fibrous debris
- Batch 2: 83.10 lbm of pulverized acrylic paint chips (6 mils), 70.20 lbm of 1/64" paint chips, 6.60 lbm of 1/8" to 1/4" paint chips, 0.30 lbm of particulate Min-K debris, 3.40 lbm of LDFG (small NUKON) debris, and 1.05 lbm of Lead Blanket Covers (fines)
- Batch 3: 0.40 lbm of LDFG (large NUKON) debris and 0.40 lbm of LDFG (largeintact) (large NUKON) debris
- Batch 4 to 6: 3.2 gallons of chemical debris (AlOOH)
- Batch 7 to 42: 1.9 gallons of chemical debris (AlOOH)

Testing was done conservatively with only 5 inches of submergence. No vortices or bore holes were observed during testing.

RAI 29

A flow sweep was performed at the end of the head loss testing to confirm laminar flow through the debris bed. See page 44 of Attachment D.

Head loss due to debris (after subtracting the clean strainer head loss) was 0.60672 ft at an average temperature of 95.1 degrees F.

<u>Head Loss Extrapolation</u>

RAI 28

Head loss extrapolation was based on the head loss data (raw data) which was collected during Test 4 until termination criteria was achieved (minimum of 15 pool turnovers and a head loss change of less than 1% in 30 minutes). The extrapolation was not adjusted for temperature or flow. The flow conditions for the tests were representative and bounding of the flow rates that would be experienced in the plant during recirculation after a LOCA (since the test flow rate could vary from 0% up to 5% of the designated flow). The extrapolated head loss for 30 days (T=2,592,000 sec) using the exponential curve fit is 0.7497 ft of water (see page 46 of Attachment D). This extrapolation was used in the NPSH analysis.

Because linear extrapolations are more conservative, a linear extrapolation was made for information only. The extrapolated head loss for 30 days (T=2,592,000 sec) using the linear curve fit is 4.2552 ft of water (page 45 of Attachment D).

Attachment D shows the debris interceptor curb during flume drain down. Tin powder and 1/64th inch paint chips can be seen on the debris interceptor. The attached pictures also show the strainer at the end of testing during flume drain down. From these pictures, open area can be observed. The bottom half of the strainer exhibited a heavier debris load than the top half. A uniform thin bed was not observed with the maximum (design basis) fiber loading.

RAI 15

Latent Fibers

For Test 4, 0.5 lbm of the 0.701 lbm of latent fiber was introduced to the surface approximately 5 minutes before starting the pumps. Flow was recirculated approximately 30 minutes before additional debris was introduced. Settling of latent fibers before the start of recirculation would be prototypical as described in Section 3.e.1.1. Placing a quantity of latent fibers in the flume was prototypical because it more closely simulated the transport of debris being picked up off the floor rather then being dropped at the surface (i.e. non-prototypical).

Because the behavior of these latent fibers could not be observed during head loss testing in the large flume, a separate fiber transport testing was performed in the small flume. The transport portion of the head loss flume was replicated so that the behavior of fiberglass could be documented. This test showed the latent fibers that had settled were picked up and transported when the test flow was initiated. A video of the test was provided to the NRC [Ref. 2.S].

RAI 20

Large Fiberglass

Large LDFG was prepared as described in Section 3.f.3.1. Figures 3.f-3 and 3.f-4 show pictures of the prepared large Nukon fiberglass. During testing, the pieces of large fibrous debris was observed to be sufficiently smaller than the flume width such that they could not become stuck. Note that "intact blankets" were also prepared the same as large Fiberglass.

CONSERVATISM - The conservative debris preparation resulted in both large and intact fiberglass pieces closer to smalls than to large fiberglass pieces as defined.

Debris Transport Test

This test determined the debris transport characteristics for RMI and miscellaneous debris. Based on the results of this test, certain debris constituents were removed from the preceding tests.

RMI - During the debris transport test and the start of Test 4, stainless steel (SS) RMI pieces at various sizes (0.25"x0.25" up to 4"x4") were shown not to transport since none of the RMI debris reached the debris interceptor. It was concluded that this debris constituent would not transport to the strainer nor contribute to a debris build-up at the debris interceptor which could act as a ramp for other debris to lift over the debris curb. Therefore, RMI was removed from further testing which is conservative since RMI may entrap other debris which could tumble along the flume floor.

Lead wool - Prior to Test 4, stainless steel wool was submerged in warm water. When submerged, the stainless steel wool immediately settled. Therefore, it was concluded that this debris constituent would not transport since it settled rapidly. Since the miscellaneous debris provided by PCI either did not reach the debris interceptor or would settle immediately, it was concluded that this debris would not transport to the strainer during testing and contribute to head loss. Therefore, this debris was removed from further testing which is conservative since some of this debris may entrap other debris which could tumble along the flume floor.

Lead blanket cover - 6" x 6" lead blanket covers were shown not to transport at fluid velocities of 0.1 ft/sec since none of these debris constituents reached the debris interceptor. Therefore, this debris was removed from further testing which is conservative since this debris may entrap other debris which could tumble along the flume floor.

Coatings - Curled paint chips were shown not to transport at fluid velocities of 0.1 ft/sec since none of these debris constituents reached the debris interceptor. Therefore, this debris was removed from further testing which is conservative since this debris may entrap other debris which could tumble along the flume floor.

Miscellaneous debris - Miscellaneous debris was tested separately from head loss testing to determine the amount of sacrificial area which could be blocked by such debris.

RAI 4

Laminated labels, tape, and paper-based labels were prepared for testing by boiling in water to determine if the labels would de-laminate or otherwise be affected. This preparation confirmed that the Electromark labels would de-laminate. It also indicated that various paper-based labels pulped to fiber. These paper-based labels were considered to have failed and were excluded from further testing. When calculating sacrificial area blockage, paper labels were assumed to not curl or degrade even though this phenomenon was observed in testing. See Section 3.b.3 for a description of paper labels and the sacrificial area. Several types of tape (duct, bumper sticker material, radiation tape, and paper radiation tape) were also boiled. None of the tapes substantially degraded. Hence, the tapes were tested in the flume.

During the debris transport test, the Neoprene and Hot Tar hose, nylon and tefzel tie wraps, and lamacoid labels were shown not to transport at fluid velocities of 0.5 ft/sec since none of these debris constituents reached the debris interceptor. It was concluded that these debris constituents would not transport to the strainer nor contribute to a debris build-up at the debris interceptor which could act as a ramp for other debris to lift over the debris interceptor. Therefore, this debris was removed from further testing which is conservative since this debris may entrap other debris which could tumble along the flume floor.

During the debris transport test, the stair tread, limited use labels, radiation tags, safety labels ("Caution Ear Protection Required"), and warning labels were shown not to transport at fluid velocities of 0.2 ft/sec since none of these debris constituents reached the debris interceptor. It was concluded that these debris constituents would not transport to the strainer nor contribute to a debris build-up at the debris interceptor which could act as a ramp for other debris to lift over the debris interceptor. Therefore, this debris was removed from further testing which is conservative since this debris may entrap other debris which could tumble along the flume floor.

During the debris transport test, the safety labels ("Danger Pinch Point"), unboiled radiation tape, silver tags, paper radiation tape, glass 69 tape, fire equipment inspection tags (yellow), fire equipment inspection tags (blue), Brady tape letters, gas calibration stickers, "Q" calibration stickers, 15" drain ring Electromark labels, and Electromark (S-1000) labels (2"x4", 2.5"x4", 3"x5", 2"x8", 6"x6", 1.5"x3", 4"x8", 8"x11", 6"x16", and 4"x14") were shown not to transport at fluid velocities of 0.1 ft/sec since none of these debris constituents reached the debris interceptor. It was concluded that these debris constituents would not transport to the strainer nor contribute to a debris build-up at the debris interceptor which could act as a ramp for other debris to lift over the debris interceptor. Therefore, this debris was removed from further testing which is conservative since this debris may entrap other debris which could tumble along the flume floor.

RAI 19 Although most miscellaneous debris sank readily in the cold flume water, during the debris transport test, the duct tape, bumper sticker tape, and the boiled 1" x 4" radiation tape (in Figure 6-19) were shown to float. Based on previous testing of the same duct tape in smaller pieces at Alion [Ref. 7.A.9] which did not float after boiling, it was concluded that the larger pieces of tape entrained air during boiling. Since testing was not conclusive, the floating debris was considered unacceptable and is included in the sacrificial area penalty. It was also concluded that these debris constituents would not transport to the strainer during testing since they float. Therefore, this debris was removed from further testing.

3.f.4 Strainer Qualification Calculations

3.f.4.1 Clean Strainer Head Loss Calculation

Calculation: TDI-6004-05, Clean Head Loss [Ref. 8.B.6]

Methodology

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 and fittings were added together to obtain the head loss for the entire strainer assembly configuration.

Assumptions

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 to account for uncertainty.

The total design flow per CPNPP strainer assembly is 12,420 gpm. Each strainer assembly consists of four (4) separate banks consisting of nine (9) modules each. Therefore, the theoretical design flow to each strainer assembly bank is 3,105 gpm.

In order to determine the greatest Clean Head Loss for the strainer, the minimum post-LOCA sump recirculation temperature of 120 F was utilized.

Results

The result of this calculation, specifically the Total Corrected Clean Strainer Head Loss value, is calculated to be 1.27 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.

3.f.4.2 Head Loss Calculation

The HLOSS code which was used during scoping and conceptual design was not used for strainer qualification because the code is not considered valid for the new strainer design. In iterative NUREG/CR-6224 correlation failed to converge for the CPNPP debris load. Therfore, head loss calculation are based on test data.

Calculation: TDI-6004-06, Total Head Loss [Ref. 8.B.7]

Methodology

The calculation utilized two (2) distinct methodologies based on the entire strainer assembly configuration to determine the maximum head loss:

(1) calculate the Clean Head Loss (utilizing the CPNPP specified design basis water temperatures: 120 °F, 212 °F, and 250 °F) for the CPNPP strainer [using Ref. 8.B.6, above] and

(2) determine the peak design basis head loss based on reduced scale strainer prototype testing utilizing the CPNPP specified design basis water temperatures of 250 F (assumed at initiation of recirculation with full flow and full submergence conditions), 212 °F (post-LOCA recirculation period), and 120 °F (end of post-LOCA recirculation) (adjust

from the test water temperature to the specified water temperatures) and the CPNPP specific debris mixture.

The individual head loss results obtained are added together to obtain the total design basis head loss for the entire strainer assembly configuration.

The quantity of fiber and debris used in the scale strainer testing is based on the debris load stated in the CPNPP specification [Ref. 8.A.1]. Debris testing is then used to determine if it is adequate to meet the specified design conditions. The actual scale strainer testing results are used as the basis for concluding that the strainer bounds the proposed size and design for the actual CPNPP strainer.

Assumptions

The CPNPP specified post-LOCA recirculation temperatures of 250 °F of (initiation of recirculation with full flow and full submergence conditions), 212 °F (post-LOCA recirculation period), and 120 °F (end of post-LOCA recirculation) will be utilized for head loss calculation purposes.

A flow velocity of 0.0073 fps characteristic of the CPNPP 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.

The total strainer head loss can be calculated by taking the sum of the calculated value of the Clean Strainer Head Loss] and the temperature adjusted, tested debris head loss.

Results

Temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. Testing at ARL provided the basis for concluding that boreholes or other differential-pressure induced effects did not affect the morphology of the test debris bed.

Head loss was calculated for Design (Test data) and for 30 day (test data extrapolated exponentially to 30 days).

	Clean Head Loss, Temperature Corrected ft of water at °F		
	120	212	250
Design	1.27	1.254	1.250
30 Day	1.27	1.254	1.250

	Debris Laden Head Loss, Temperature Corrected ft of water at °F		
	120	212	250
Design	0.472	0.240	0.194
30 Day	0.584	0.296	0.240

	Toral Head Loss, Temperature Corrected ft of water at °F		
	120	212	250
Design	1.742	1.494	1.444
30 Day	1.854	1.550	1.490

CONSERVATISM - Head loss was extrapolated to a 30 day sump mission time. However, the CSS mission time for LOCA is less and spray termination will reduce flow and head loss through the strainers. The Containment Spray System is capable of returning the post-LOCA environment to non-harsh temperatures in less than 14 days [Ref. 7.F.22].

3.f.4.3 Vortexing, Air Ingestion, and Void Fraction Calculation

PCI Sure-Flow® Strainer design utilizes a combination of recognized 'defense in depth' multiple vortex suppression devices – perforated plate, parallel disk plates, disk grill wires, core tube slots, module external bracing, and the resultant tortuous strainer internal flow path – all providing more than the single grating vortex suppressor recommended in RG 1.82 Revision 3.

RAI 23 The minimum flood level for SBLOCA at the start of switchover to ECCS recirculation assures the core tube is covered by over nine (9) inches of water and the strainer would be fully submerged within 13 minutes (See Section 3.f.1 and 3.g.1). Clean strainer head loss is less than design becuase flow rate are only 10% of design. Because there is little or no head loss in addition to clean strainer head losses, vortexing or flashing within the strainer is not credible.

An analysis of expected head losses was performed for the partially submerged strainer scenario. The first step of this analysis was to simply compare the minimum submergence from the minimum expected water level to the top of the core tube. Per the CPNPP design the top of the core tube is 21 – 17/32" above the floor at elevation 808'. Based on a minimum containment flood level for an SB LOCA scenario of 810.56', the minimum submergence is expected to be 810.56' – 809.7943' or 0.766'.

Determining the clean strainer head loss at either 400 gpm (typical for SB LOCA with only CCP injection) or 1200 gpm (typical for SB LOCA with CCP and SIP injection) and comparing the clean strainer head losses against the minimum submergence shows that the clean strainer head loss at any point in the operating range of temperatures, for either flow rate, is less than the 0.766' submergence. The clean strainer head losses were estimated per the methodology used to determine the clean strainer head losses given in PCI Report TDI-6004-05 [Ref. 8.B.6] using the 120 °F, 212 °F, and 250 °F temperatures and the 400 gpm and 1200 gpm flowrates.

The clean strainer head loss was chosen based on the specifics of the SB LOCA providing less damage, lower flowrates and velocities for debris transport, and lower approach velocities to the strainer modules. However, if the same analysis as was done above for clean strainer head loss values, using the clean strainer head loss values and conservatively adding the using the total debris losses from the CPNPP strainer testing (corrected for temperatures), the values are still less than the submergence available. It is readily seen that the debris value used for this assessment is very conservative. It represents debris losses early in the event between ECCS switchover and CS switchover. The debris head losses included the full fiber and particulate effects from the testing at the full design flow rate (without any correction made for reduced debris or reduced flow). The values for debris head losses are taken from the final CPNPP testing results, i.e., 0.60672 feet of water at 95.1 °F. Correcting to 120 °F yields 0.472 feet, at 212 °F it is

0.240 feet and at 250 °F it is 0.194 feet of water. These values are given in PCI report TDI-6004-06 [Ref. 8.B.7] Adding these values to the clean strainer values estimated above yields the values shown below and these (conservatively estimated) values remain less than the core tube submergence of 0.766 ft.

Calculation for full design flow conditions: TDI-6004-07, Vortex, Air Ingestion & Void Fraction [Ref. 8.B.8]

Methodology
The calculation utilized classical 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 detemination in accordance with various USNRC guidance documents, specifically RG 1.1 [Ref. 9.M].

A flow velocity of 0.0073 fps characteristic of the CPNPP 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 CPNPP 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.

In addition, the minimum submergence with full flow is greater than 6 inches which is sufficient to preclude vortexing through floor grating.

Testing with conservatively low water levels with and without debris has shown that vortexing would not occur.

Air Ingestion - The guidance of RG 1.82 Rev. 3 [Ref. 9.G] 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 CPNPP PCI Sure Flow® suction strainer is 0.159 (approximately 37% lower than the USNRC guidance found in RG 1.83 [Ref. 9.G]). Therefore 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 CPNPP Void Fraction and concluded that flashing and subsequent void fraction formation would not occur.

Containment accident pressure was assumed to be 38.5 psia based on the maximum post-LOCA sump water temperature (265 °F) and credited in evaluating whether flashing would occur across the strainer surface. In addition, the maximum total strainer head loss (1.490 feet of water from 3.f.4.2, above) was compared to the NPSH margin and it was concluded that there would be 0% void fraction associated with the strainer discharge into the sump.

Given that the minimum submergence for LBLOCA is greater than 1.25 feet which is greater than the debris load head loss at any temperature, it is not likely for any flashing to occur across the debris bed.

The corresponding minimum submergence for the core tube is 3.00 feet which is greater than the total strainer head loss at any temperature Therefore, it is not likely for any flashing to occur across the core tube or the entire strainer.

Section 3.g 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.

NPSH calculations are based on the following:

ME-CA-0000-5066, Calculation of Minimum Flood Level in the Containment Following a Large Break LOCA, Small Break LOCA and MSLB [Ref. 7.F.17]

ME(B)-389, RWST Setpoints, Volume Requirements, and time depletion analysis [Ref. 7.F.18]

ME(B)-325, Head Losses between Containment Sumps and RHR Pumps During Recirculation and NPSHa [Ref. 7.F.19]

ME-CA-0232-5416, Evaluation of GSI-191 Impacts on the Containment Spray System Performance [Ref. 7.F.20]

ME-CA-0232-4006, NPSHa for Containment Spray Impellers Using Nominal Test Data [Ref. 7.F.21]

TDI-6004-06, Total Head Loss, Comanche Peak Steam Electric Station [Ref. 8.B.7]

3.g.1 Design Basis

- *Applicable maximum pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level:*

	ECCS	CSS	TOTAL
One Train (gpm)	4,900	7,520 (2 pumps x 3760)	12,420
Two Train (gpm)	9,000	15,040 (2 trains x 7520)	24,040

REF. 7.A.1

Each train has its own sump and strainer. ECCS suction is one RHR pump per sump with the two trains operating in parallel. Single failure of one RHR pump results in a maximum flow of 4900 gpm to the two trains. With no failures, the maximum RHR pump flow is 4500 gpm per pump. CSS suction is two pumps per sump with each train operating independently.

Peak sump temperature at the initiation of recirculation is approximately 250°F. Peak sump temperature prior to initiation of recirculation is approximately 260°F. Specific peak sump temperatures depend on the event being analyzed and the initial assumptions. Determination of the minimum flood level is based on a sump temperature of 200°F.

Minimum containment water level for the design basis LBLOCA was determined to be 811.12 ft (3.12 ft above floor level) at the initiation of ECCS recirculation and 813.21 ft (5.21 ft above floor level) at the initiation of spray recirculation. A variety of cases were analyzed in addition to LBLOCA, and these included SBLOCA with and without accumulator injection, MSLB, and several other cases of interest.

Two train operation resulted in the lowest flood levels at the time of switchover to recirculation.

	ECCS Recirculation	Spray Recirculation
LBLOCA	El. 811.12	El. 813.21
SBLOCA	El. 810.56	El. 812.82
MSLB	N/A	El. 812.64

Note that SBLOCA (without accumulator injection) bounds MSLB in that the flood level is comparable and the flow rates are 400 to 1200 gpm higher (per train). In addition, the mission time for the sump for MSLB is only approximately one day based on Ref. 7.F.22.

- *Assumptions used in the calculations for the above parameters and the sources/bases of the assumptions:*

The ECCS recirculation flow rate is the design basis ECCS recirculation rate used in the plant design. Spray recirculation flow rate is determined directly using the system resistance and tested spray pump performance.

The sump temperature data is taken from the accident analysis which includes a maximum sump temperature analysis. The sump temperature used to calculate the containment flood level was taken as 200°F as this yielded a specific volume lower than the expected sump temperatures at the initiation of recirculation.

Sensitivity analysis performed in the flooding analysis for long term scenarios confirmed decreasing the sump temperature to ambient (120°F) in the long term would have no significant negative impact.

Details related to the determination of containment flood levels are provided below.

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

NPSH requirements were taken from the vendor supplied pump performance data.

- *Friction and other flow losses.*

Friction losses for the protective cage around the sump strainers, the sump strainers clean head loss, the entrances into the suction piping and the pipe and fitting friction from the sumps to the inlets of each pump are included as losses in the determination of NPSHa. Note that the design clean strainer head loss at full flow is applied for the ECCS pumps although at the initiation of ECCS recirculation only ECCS flow will be drawn through the strainers. The scenario used for determination of friction losses in the suction paths to the ECCS and Spray pumps was the LBLOCA scenario. SBLOCA scenarios have lower system flowrates and hence small strainer losses.

Friction losses are based on the design system flowrates and no single failures of pumps or systems that would have the effect of decreasing the frictional losses to either the Spray pumps or the ECCS pumps. The redundant ECCS pump suction paths and Spray pump suction paths were each analyzed to identify the individual flow path that had the highest line losses and hence the smallest NPSH margins. The NPSH margins identified below are based on the limiting case suction line losses for each pump group.

- *System response scenarios for LBLOCA and SBLOCAs.*

  For a LBLOCA the scenario develops as follows. The RCS inventory is released to the containment and the SI accumulators inject their inventory into the RCS.

  The line breaks, and SI is actuated by RPS instrumentation and begins ECCS injection. At this point containment atmosphere is heating up and the containment pressure is increasing. ECCS actuation refills the RCS to the elevation of the break. The SI signal also starts the spray pumps, and they start and operate in minimum flow recirculation mode until the containment HI pressure permissive is achieved and the spray system begins to remove heat from the containment atmosphere.

  The sprays and released RCS inventory start collecting in the various locations throughout containment where they can be held up. It is assumed that all the holdups fill before flooding starts to occur to minimize the containment flood level at the initiation of ECCS recirculation. Once all of the holdups are filled, the water is assumed to drain to the containment floor and the flood level starts to rise. Once the RWST reaches low-low level, ECCS switchover to recirculation is initiated and the suction of the ECCS pumps is switched to the sumps. During ECCS switchover, the spray pumps are still taking suction from the RWST.

  Flood level in the containment continues to rise, and when the RWST level setpoint for the initiation of Spray recirculation is reached the suction of the Spray pumps is manually switched to the sumps.

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  For a SBLOCA the scenario develops in a similar manner although the accumulators may not inject if pressure doesn't drop sufficiently, and the sprays may not actuate for a longer period of time as the containment pressure response will be significantly less. Switchover of the ECCS pump suction paths will occur at the same setpoint, and when the Spray switchover setpoint is reached the Spray pumps suctions will be switched over to the sumps. As described below, the containment minimum flood level for a SBLOCA includes no credit for RCS inventory adding to the sump flooding. Loss of inventory for flooding due to RCS shrinkage was included. Because Comanche Peak does not have safety grade fan coolers, all containment heat removal post accident is via containment spray. Calculations have been performed [Ref. 7.F.41] that show sprays will actuate prior to ECCS recirculation even in the event of a two inch SBLOCA where the recirculation flow rate is only 400 gpm. The minimum calculated water level at ECCS switchover for a

SBLOCA is 810.56 ft. which is 0.56 ft higher than the strainer specification requirement. The strainer core tube would be submerged by at least 9.22 inches at initiation of recirculation. [See P-3.j.2-2b] With corresponding SBLOCA recirculation from 400 to 1200 gpm, the initial approach velocity would be from 0.0005 fps to .0014 fps (19% of LBLOCA design). Water level would be rising at more than one inch per minute for all design basis LOCA breaks due to spray injection. Approach velocities would be decreasing accordingly.

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

All ECCS and CSS pumps start automatically and continue to run through switchover from injection to recirculation. The ECCS system is designed for the pumps to run continuously during switchover from cold leg recirculation to hot leg recirculation and back.

For the purposes of determining the minimum containment flood level and NPSHa all of the ECCS pumps and Spray pumps are assumed to be operating. This was done to maximize the water holdups throughout the containment which acts to minimize the containment flood level. It was also done to maximize the strainer and suction line friction losses to minimize the determination of NPSHa.

- *Single failure assumptions relevant to pump operation and sump performance.*

The sumps were evaluated for one and two train operation bounding any single active failure.

In general, no single failures of pumps were governing when calculating the containment minimum flood levels as full two train operation maximized flowrates and maximized holdups which corresponded to minimum flood levels. Full flowrates were also postulated for NPSHa calculations as this maximized the line, strainer and fitting losses in each pump suction line. No assumptions in the NPSHa analysis were made to minimize strainer flow to minimize strainer head losses such as taking suction for spray pumps from one sump and ECCS pumps from the other.

Single failures were applied to values taken from the accident analysis such as containment temperatures used to calculate steam holdup in the atmosphere. A single train accident calculation yielded higher atmospheric temperatures which yielded higher steam holdups.

- *Determination of containment sump water level.*

  The minimum sump water level is determined by calculation.

  The minimum containment flood level is determined by first the minimum amount of water available for flooding. This initial water inventory is based on the minimum RWST volumes and the accident scenario under analysis. Once the amount of water available for flooding is determined, the amount of water captured in various holdup scenarios is determined, and that value is subtracted from the initial inventory of water for flooding. The holdup scenarios include steam in the atmosphere, droplet transit time in the atmosphere, various geometric holdups in supports, equipment, etc., rooms below the sump elevation in the containment, volumes to fill dry piping, and a variety of plant specific holdups. The volume of the containment is then determined as a function of elevation. The containment minimum flood level is then determined by taking the net available flood water and dividing by the sump cross sectional area.

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

  The major assumptions made to ensure a minimum flood level in the containment are as follows:

  - Minimum RWST injection volumes are used with negative impact from instrumentation errors.

  - Minimum net RCS or SG inventory values are used for the scenario under consideration.

  - The volume of the Chemical Addition Tank is neglected and not assumed to contribute to the water inventory. However, it should be noted that this volume is credited to offset any leakage in the system recirculating the sump water out side containment over 30 days.

  Conservatism - The floor drain system and the hydrogen mixing vents in all of the intermediate slab elevations in the containment are assumed not to provide a drainage path for water held up on these slabs. The only drainage from these slabs is assumed to be through opening in the slab perimeter. Analysis performed for other reasons has shown that the hydrogen mixing vents provide a substantial drainage path through each slab, and due to their number and widespread locations they will not all be clogged with debris regardless of the accident or its location. However, no credit was taken for these paths.

All identified holdup penalties are assumed to fill prior to any accumulation of flood level in the containment including the incore instrument room below the reactor which is the single largest holdup penalty identified. An analysis was performed to estimate the time required to fill the areas below the reactor and that analysis indicated the subject volume would not be filled prior to the initiation of ECCS recirculation. However, to minimize flood level at this point, it was assumed that all holdups filled prior to any increase in containment flood level.

Spray droplet size assumed for atmospheric holdup is the minimum size which has the slowest fall speed and maximizes atmospheric droplet holdup.

Holdups on the major sprayed slabs in the containment are based on two train spray operation as this maximizes the holdups on the slabs.

The containment atmosphere is assumed to be at 0% Relative Humidity prior to the accident for the purpose of determining the steam holdup in the containment atmosphere. Bounding values of the atmospheric temperature at the initiation of ECCS recirculation (for LOCAs) or Spray recirculation (for MSLBs) are assumed. The atmospheric holdup is not reduced for any of the analyzed scenarios except for the long term case with RCS and atmospheric cooldown.

No credit is taken for the containment volume displaced by piping, supports, equipment, etc within the flood pool. The volume of the flood pool is only reduced by the volumes of the physical concrete structure and the reactor vessel.

- *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.*

The minimum amount of water available for flooding in the minimum containment flood level analysis is reduced by the amount of water required to fill the dry portions of both spray headers and all four sump suction lines up to the normally closed sump isolation valve. A holdup penalty is determined for the time required for spray droplets to fall to the various surfaces and another penalty is determined for the amount of water that is draining from higher elevations to lower elevations by gravity flow. A holdup penalty is determined due to the steady state holdups on the major sprayed horizontal elevations that have drainage perimeters. To address surface condensation and other unquantifiable potential holdups an arbitrary holdup penalty was taken. This penalty was equivalent to a quantity of water equal to a 2" depth across the entire free cross sectional area of the containment.

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

  The flooding analysis determined the cross sectional area of the containment at each elevation where the cross sectional area changed to determine the pool flood level. In the flooding analysis, structural concrete components, columns, walls, curbs and the reactor vessel, were credited as reducing the floor area of the pool area. Miscellaneous equipment, support steel, piping, etc. was not credited as displacing any water or raising the calculated pool water level.

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

  The potential sources of water that contribute to the pool volume that were considered in the determination of the minimum flood level are as follows:

  A. Minimum injection volume from the RWST before the initiation of ECCS recirculation was 300,000 gallons.

  B. Minimum injection volume from the RWST before the initiation of ECCS recirculation was 440,300 gallons.

  C. The analysis that determined the minimum available RWST volume was based on determining a design minimum amount of available water. Actual water availability will be greater than or equal to the specified amounts. For details see calculation ME(B)-389 [REF. 7.F.18].

D. For LBLOCA the RCS volumes contributing were 210,000 lbm from the Accumulators and the minimum net contribution from the spectrum of breaks analyzed was 212,000 lbm from RCS system.

E. For SBLOCA the RCS volumes contributing were either zero or 210,000 lbm depending on whether the accumulators injected. Both were analyzed.

F. The determination of RCS volumes available for flooding was taken from the mass and energy balances developed and used in the determination of RCS blowdowns for the containment accident analysis. The value use was the case that contributed the minimum net RCS inventory to the pool volume.

G. For MSLB an initial SG inventory of 105,000 lbm was used. It was assumed that there was no contribution from connecting piping or feedwater flow prior to feedwater isolation.

H. The SG inventory was taken from the NSSS vendor SG design information for the power level that had the lowest SG inventory over the range of the plant operation. Again this was done to minimize the contribution to the pool volume.

- *Credit taken for containment accident pressure in determining available NPSH, description of the calculation of containment accident pressure used in determining the available NPSH.*

  Credit is not taken for containment accident pressure when determining NPSHa. It was assumed that the vapor pressure of the sump fluid was equal to the containment accident pressure.

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

  As stated above, no credit is taken for containment accident pressure when determining NPSHa

- *Containment accident pressure set at the vapor pressure corresponding to the sump liquid temperature.*

For purposes of determining NPSHa, it was assumed that the vapor pressure of the sump fluid was equal to the containment accident pressure.

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

The minimum NPSH margins were typically calculated at 212 °F with no debris load.

The minimum RHR pump margin with no strainer head loss is 8.65 ft at the initiation of ECCS recirculation [El. 811'] and 11.38 ft once spray recirculation is initiated [El. 813']. [Ref. 7.F.19]

The minimum Spray pump margin with no strainer head loss is 6.59 ft at the initiation of Spray recirculation at El. 813'. [Ref. 7.F.20]

The maximum clean strainer head loss is 1.27 feet when both RHR and Containment Spray are in operation.

Therefore, the spray pump margin is the limiting element. The maximum total strainer head loss due to the design basis debris load extrapolated to 30 days at 212 °F is 1.55 feet. Subtracting the strainer head loss from the Containment Spray margin of 6.59 ft. above, yields a conservative minimum NPSHa margin of 5 feet.

<u>CONSERVATISM -</u> Both of the NPSHa margins reported above are based on the minimum flood levels specified in the Sump Strainer Specification. Actual margins are slightly higher as the elevations in the Strainer Specification are more conservative (lower) than the minimum flood levels determined. In addition, the minimum flood levels are determined at the point of initiation of recirculation with maximum holdup of steam and water above the sump pool. The flood level will increase with time as the containment cools and the sprays are terminated.

RAI 35 The total strainer head loss was also calculated (for information only) to be 1.854 feet at 120 °F since the chemical precipitates would not be present at the temperature and minimum flood level corresponding to the point of switchover to recirculation. Although the head loss is approximately 0.3 feet higher at the lower temperature, the corresponding increase in flood level due to condensation of steam [Ref. 7.F.17]would more than offset it. In addition, this increase is

insignificant in comparison to the air partial pressure margin (below).

CONSERVATISM - The calculation of NPSH margin at the minimum flood level corresponding to the initiation of recirculation with the debris loaded head loss after 30 days of recirculation is a significant conservatism.

3.g.2 Air Partial Pressure Margin

An evaluation of the air partial pressure was performed [Ref. 7.F.25].

Method: Determine the containment air partial pressure at maximum normal temperature, maximum humidity and lowest allowable operating pressure. Then reduce containment air temperature to a minimum based on minimum SSI/chilled water temperature and determine a new minimum initial air partial pressure. Next, allow for containment leakage and assume only air is released, thereby creating a time dependent containment air partial pressure that will decrease with event progression. NPSHA can then be calculated using Eq. 1.

When calculating NPSHA, the typical governing equation is as follows:

$$NPSHA = H_p + H_{el} - H_{vp} - H_{fl} \qquad \text{(Eq. 1)}$$

where,
H_p=absolute pressure head
H_{el}=elevation head
H_{vp}=vapor pressure at pumped fluid temperature
H_{fl}=friction losses upstream of pump suction flange

For Comanche Peak, implementation is as follows:

Assumptions:

1.	Lowest normal operating containment pressure	14.2 psia
2.	Containment volume	2.99E+6 cu ft
3.	Maximum normal containment temperature	120 °F
4.	Containment humidity	100%
5.	Minimum SSI/chilled water temperature	40 °F
6.	Containment leakage consists entirely of air (conservative)	
7.	Containment leakage is driven by a 50 psi difference between containment and	

outside atmosphere (conservative)

8. Containment air temperature during the event does not contribute to credited air pressure (conservative).

Calculations:

1. Initial air partial pressure = 14.2 psia - vapor pressure at 120 °F = 14.2 - 1.7 = 12.5 psia
2. Minimum air partial pressure at 40 °F = (460 + 40) / (460 + 120) * 12.5 = 10.7 psia
3. Minimum air mass = 144 P V / R T = (144 * 10.7 * 2.99E+6) / (53.3 * 500) = 1.73E+5 lbm
4. Containment air mass leakrate at 0.1% per day at 50 psig = 0.001 * (144 * 64.7 * 2.99E+6) / (53.3 * 580) = 901 lbm per day
5. Time dependent air partial pressure = 10.7 * (1.73E+5 - (901 * t)) / 1.73E+5 where t is event duration in days

t (days)	partial pressure (psia)	partial pressure (ft)
1	10.6	24.4
10	10.1	23.3
30	9.0	20.8

A containment sump temperature history following a single train large break LOCA* is tabulated below:

t (days)	sump temperature (°F)	vapor pressure (psia)	vapor pressure (ft)
1	161	4.9	11.3
10	131	2.3	5.3
30	113	1.4	3.2

6. Conservatively assuming that the containment total pressure equals the air partial pressure, that is, there is no vapor pressure left in containment, then *additional* NPSH margin *gained* is as follows:

t (days)	additional margin (ft)
1	24.4 - 11.3 = 13.1
10	23.3 - 5.3 = 18.0
30	20.8 - 3.2 = 17.6

As can be seen, once sump temperature decreases below about 196 °F (vapor pressure of 10.7 psia), additional NPSH margin begins to accumulate and is dependent upon the assumed containment leakrate and transient sump temperature. For a single train LOCA, this occurs about 7 hours into the event.

By crediting a minimum containment air partial pressure with assumed containment leakage, significant NPSH margin can be gained during the cool down of the containment sump fluid. This occurs early in the event for a large break LOCA and therefore would be available during any adverse conditions that may be experienced at the containment sump strainers as the event progresses. The proposed method does not credit containment air pressure changes due to event driven containment air temperature changes and is therefore conservative.

Section 3.h Coatings Evaluation

The coatings evaluations perfomed have determined the plant-specific ZOI and debris characteristics for coatings for use in determining the contribution of coatings to overall head loss at the sump screen as well as bypass effects on downstream components.

3.h.1 Summary of types of coating systems used in CPNPP containment

The primary field-applied "Acceptable" coatings systems in containment for Comanche Peak are CZ-11 for high heat applications, a CZ-11/Phenoline 305 system for steel and a Nutec 11S/Nutec 11/Nutec 1201 system for concrete. Carboline191 was used as touch-up for CZ-11.

While these are the primary coating systems for containment, other similar systems were used in limited applications. For example, the following "Acceptable" coatings systems have been used for steel maintenance coating work: Carboline 801, Carboline 890, and Amerlock 400. Also, the following "Acceptable" coatings system has been used for concrete maintenance work: Starglaze 2011S /Starglaze 2011/Carboline 890.

DBA-unqualified coatings systems include inorganic zinc, epoxy, silicones and alkyds.

3.h.2 Bases for assumptions made in post-LOCA paint debris generation and transport analysis

The post-DBA debris evaluations of all coatings were based on NEI-04-07 [Ref. 4.A] and/or appropriate testing as discussed below.

Because Comanche Peak protective coatings were declassified during construction of the plant as described in the response to NRC Generic Letter 98-04 [see Ref. 2.K], 100% DBA-unqualified coatings were initially assumed to exist for GSI-191 analyses consistent with the licensing basis assumed 100% failure. However, all of the coatings were applied under either the Comanche Peak 10CFR50, Appendix B QA program or the Comanche Peak Non-Appendix B QA program. [See Ref.s 2.K, 2.L, and 2.M]

Containment coatings are generally subject to applicable portions of 10CFR50, Appendix B because their failure has the potential to be detrimental to Safety Related Structures, Systems, and Components. The CPNPP quality assurance program for such items is covered by the Comanche Peak Non-Appendix B QA program (Appendix D of the QA Manual).

As described in TXX-05162 [Ref. 2.A], a reevaluation of all declassified coatings inside containment was performed. This assessment and its goals included the following key elements:

Revising the Current Licensing Basis to upgrade containment building protective coatings from "declassified" to "acceptable" status (per ASTM D-5144 [Ref. 12.B]).

- A suitability for application review of applied protective coatings was performed per ASTM D-5144 – using EPRI "Guideline on Nuclear Safety-Related Coatings" TR-1003102 (formerly TR-109937) for guidance.
- The protective coatings program was assessed and revised using updated industry standards (i.e., ASTM vs. obsolete ANSI standards).
- The protective coatings program was assessed and revised using recommendations of EPRI TR-1003102.

Revising the coatings program to restore a coatings quality assurance program consistent with the latest industry standards for Service Level I coatings endorsed by the NRC in Reg. Guide 1.54, Revision1 [Ref. 9.J] and to restore qualification for containment coatings.

RAI 30 The reevaluation of all declassified coatings inside containment was performed under SMF-2004-002882-00 [Ref. 3.E] using plant records. Where records were insufficient, sampling and testing were performed (e.g. to establish material traceability). The suitability for application review of applied protective coatings was performed by ER-ME-124, "Evaluation of CPSES Protective Coatings" [Ref. 5.E].

All containment coatings were applied and maintained under either the Comanche Peak 10CFR50, Appendix B QA Program or the Comanche Peak Non-Appendix B QA program. The Non-Appendix B QA program includes criteria to achieve quality coating material and workmanship; namely, the use of coating materials that meet the design-basis-accident (DBA) conditions, compliance with the technical requirements of paint application specifications, quality verification of coating work, and traceability of coating quality verification documentation.

The program procedure for protective coatings, STA-692 [Ref. 14.A], was revised. There are three classifications: Qualified, Acceptable, and Unqualified in accordance with the guidance in EPRI TR-1003102 [Ref. 4.C] and ASTM D-5144 [Ref. 12.B]. Qualified and Acceptable coatings are referred to as "qualified". Unqualified coatings, which includes indeterminate coatings, are included on the Coatings Exempt Log (CEL) for each unit. The CEL for each unit was revised to include coatings which require additional testing or analysis to classify as Qualified or Acceptable.

The change to the licensing basis was completed under SMF-2004-002882-00 [Ref. 3.E]. The CPNPP FSAR is being updated in accordance with 10CFR50.71(e). [Ref. 9.C]

The reevaluation of 100% of the coatings inside containment resulted in a unqualified coatings exempt log (CEL) for each unit which documents all coatings not found to be qualified or acceptable. The Unit 1 CEL by generic coating system is as follows:

Unit 1 Unqualified Coatings [Ref. 7.A.19]		
Generic Coating System	**Debris Quantity (lbm)**	**Surface Area (ft²)**
Inorganic Zinc	8.81	85.0
Inorganic Zinc/Epoxy	34409.27	176339.53
Epoxy	5340.88	11264.08
Alkyd Enamel	101.92	5308.5
Alkyd/Epoxy	10.51	100.75
Bare Concrete	0.00	733.82
Unit 1 Total	**39871.4**	**193831.68**

The Unit 2 CEL total is as follows:

Unit 2 Unqualified Coatings		
	Debris Quantity (lbm)	**Surface Area (ft²)**
Unit 2 Total	**12,349**	**63.498.4**

Unit 1 is bounding for Unit 2.

CONSERVATISM - Note that "unqualified" coatings are all actually "indeterminate" coatings. As shown in various tests (e.g. Ref. 4.D), they may or may not fail completely during a design basis accident. They are conservatively assumed to fail if classified as Unqualified. This is a significant conservatism in the evaluation of emergency sump performance.

Zone of Influence

The debris generation assumption made for "Qualified" and "Acceptable" coatings in the zone of influence of the LOCA is based on testing performed on representative coating systems. A spherical ZOI of 4D for "Acceptable" epoxy was selected based on two separate tests.

WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA Qualified/Acceptable Coatings", Revision 0 dated June 2006. [Ref. 7.E.6] concluded that a spherical ZOI of 4D is conservative for the "Acceptable" epoxy coatings comparable to those used by CPNPP.

In addition, a ZOI evaluation of the specific "Acceptable" containment coatings at CPNPP was performed using the results of the Coatings Performance Tests conducted by FPL and Areva NP (JOGAR Testing). This evaluation concluded that a spherical ZOI of 4D is conservative for "Acceptable" epoxy coatings such as those used by CPNPP. [Ref. 7.B.1]

RAI 31 Based on the assessment of coatings under Ref. 3.E, only minor quantities of concrete coatings are unqualified whereas there are large quantities of unqualified steel coatings. Therefore:

- All concrete coatings within a 10D ZOI are considered "Acceptable". Therefore, a 4D ZOI has been justified and was assumed for debris generation.
- Because some steel coatings within a 10D ZOI were conservatively assumed to be DBA-unqualified, a 4D ZOI was not considered to be justified. Therefore, a 10D ZOI was assumed for debris generation.

CONSERVATISM - Acceptable steel coatings between 4D and 10D are conservatively included in the debris. DBA-unqualified steel coatings in the 10D ZOI are double counted in the debris.

Coatings under intact insulation were not assumed to fail. However, the coatings under destroyed insulation were assumed to fail within a 10D ZOI.

For debris generation and transport analysis, 10 micron particles were assumed for "Acceptable" epoxy coatings within the 4D ZOI. "Acceptable" coatings outside the 4D ZOI were not assumed to fail.

For debris generation and transport analysis, 10 micron particles were assumed for DBA-unqualified coatings within a 10D ZOI.

DBA-unqualified Coatings

In addition to the coatings within the ZOI, 100% of the DBA-unqualified and degraded coatings outside the ZOI were assumed to fail as 10 micron particles except where based on testing and plant specific conditions as described below.

Testing was performed for Comanche Peak by Keeler & Long PPG [Ref.7.D.1] and transmitted to the NRC for information. [Ref. 2.F]

Keeler and Long Report No. 06-0413, Design Basis Accident Testing of Coating Samples from Unit 1 Containment, TXU Comanche Peak SES [Ref.7.D.1], has been reviewed and found applicable to the degraded DBA-qualified epoxy and inorganic zinc coatings applied at CPNPP. In the test, epoxy topcoat / inorganic zinc primer coating system chips, taken from the Comanche Peak Unit 1 containment after 15 years of nuclear service, were subjected to DBA testing in accordance with ASTM D 3911-03. [Ref. 12.A] In addition to the standard test protocol contained in ASTM D 3911-03, 10 m filters were installed in the autoclave recirculation piping to capture small, transportable particulate coating debris generated during the test.

The data in this report shows that inorganic zinc predominantly fails in a size range from 9 to 89 microns with the majority being between 14 and 40 microns. Therefore, a conservative size of 10 microns was assumed for transport analysis and head loss testing of inorganic zinc.

The data in this report also showed that DBA-qualified epoxy that has failed as chips by delamination tend to remain chips in a LOCA environment. The data showed that almost all of the chips remained in the test trays which had holes 1/32 inch in diameter.

Subsequent to the Keeler & Long test, a paint chip characterization on the chips that were generated from the test was performed by Alion Science and Technology [Ref. 7.A.11] and provided to the NRC for information. [Ref. 2.G]

The scope of the characterization was to perform a size distribution analysis of paint chips (as best possible). This involved a combination of visual, optical magnification and/or Scanning Electron Microscopy (SEM) of the smaller sizes or coating thickness. Size distribution analysis in this case was quantifying a size distribution to fit the NUREG/CR-6916 [Ref. 9.I] distribution, which is comprised of the following categories:

- Small (1/64th to 1/32nd inch),
- Medium (1/8th to 1/4th inch),
- Large (1-2 inch) flat
- Large (1-2 inch) curled.

The characterization also binned the paint chips into a distribution that was more distinct than that noted above. Chips that were in length ½ in. to 1 in. and from ¼ in. to ½ in. were also included in a size distribution as medium large and medium small.

The conservatively determined results of the characterization used in debris generation [Ref. 7.A.2] were as follows:

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%

Therefore, a chip diameter of greater than or equal to 1/64 inch may be used for transport for 87.6% of Phenoline 305 epoxy coatings shown to fail as chips by delamination. The balance that is assumed to be 6 mil chips is a very conservative estimate of the size distribution. The above size distribution based on testing is used in lieu of the default size of 10 microns or the default area equivalent to the area of the sump-screen openings for coatings size. This is further discussed under testing below.

Carboline Phenoline 305, according to manufacturer's published data sheets and MSDS's, is conservatively representative of the other DBA-qualified/Acceptable epoxy coatings found in US nuclear power plants, including Mobil 78, Mobil 89, Amercoat 66, Keeler & Long 6548/7107 and Keeler & Long D-1 and E-1. [Ref. 7.G.1]

The Coatings Exempt Logs (CELs) provide minimum and maximum estimates of coating quantities based on the range of applied coating thickness and density information. The estimates for maximum thickness in the CEL were grouped according to inorganic zinc, epoxy, and alkyd enamel and used to calculate volume and mass for each generic coating material. These values were used to calculate a volume average density. The range of average thicknesses for degraded DBA-qualified epoxy on the CELs is 3 to 22.5 mils. The Unit 1 CEL is bounding for unqualified coatings. To determine the mass of epoxy on the Unit 1 CEL, a distribution of epoxy coatings was determined based on the following range of thicknesses: 4% (3 to 7 mil), 71% (7 to 10 mil), and 26% (10 to 23 mil). A thickness distribution of IOZ coatings was determined based on the following range of thicknesses: 3% (0.5 to 2.5 mil) and 97% (>2.5 to 4.3 mil). Therefore, the coatings on the CEL were assumed to fail with this distribution.

OEM Coatings

For OEM coatings, Design Basis Accident Testing of Pressurized Water Reactor Unqualified Original Equipment Manufacturer Coatings, EPRI 1011753 [Ref. 4.D], was used to determine that 10 microns is a very conservative assumption for particle sizes. None of the OEM coatings failed as chips. Therefore, 10 micron particle sizes were used for transport and head loss analyses.

This report also showed that, on average, much less than half of OEM coatings detached and failed during testing. Based on the EPRI test results and the conservative assumption of 10 micron particle size, 100% failure of all OEM coatings is overly conservative. CPNPP has determined based on the review of the EPRI Report No 1011753 for Original Equipment Manufacturers (OEM) unqualified coatings that CPNPP could not reduce the failure percentage across the board for all non qualified OEM coatings. It has been determined, based on the review of the EPRI report and plant specific coating types, that a reduction in the failure percentage for the epoxy could be justified if enough information were known. The failure percentage for specific epoxy types could be less than 50% which bounds the worst performing sample for this type in the test data. However, because the amount of epoxy on OEM equipment is small and detailed information on the OEM coatings are not readily available, 100% failure of all OEM coatings was assumed.

Therefore, the following conservative failure percentages were assumed for OEM coatings.
Epoxy – 100%
Inorganic Zinc – 100%
Alkyds – 100%
Urethane – 100%
Other – 100%

No debris was included in transport and head loss analysis for unqualified coatings outside the ZOI that are a) within an inactive sump, b) covered by intact insulation, or c) otherwise isolated from spray and transport to the sump.

<u>CONSERVATISM</u> - Note that the assumed quantity of unqualified coatings is very conservative. Additional evaluations and/or testing may be performed at some time in the future to identify and quantify margins in the assumed coating debris.

3.h.3 Head Loss Testing

For head loss testing, representative surrogates with similar density, size, and shape characteristics to the debris generation and transport assumptions above were selected.

For coating debris from epoxy, phenolics, silicones, enamel and alkyds specified as powder, pulverized acrylic coating powder which has similar density, size, and shape characteristics to these coatings was used as a surrogate material. This surrogate is conservative when used for OEM coatings and all epoxy coatings within the ZOI. [Ref. 8.D.4]

For coating debris from inorganic zinc, the surrogate used was tin powder with a particle size range of ~10 to 44 microns. Tin powder has similar density, size, and shape characteristics as inorganic zinc. The particle size selected for all DBA-unqualified inorganic zinc coatings was based on the Keeler and Long Report No. 06-0413 as discussed above. This size is also consistent with the size assumption for inorganic zinc within the ZOI. This surrogate is conservatively used for all inorganic zinc coatings.

Because CPNPP is a low fiber plant, the possibility of head loss caused by chips was investigated. For epoxy and phenolic coating debris specified as chips, the surrogate used in the original prototype testing with no fiber was formed from the dry film of Carboline® Carboguard® 890 broken into pieces forming a spectrum of sizes. No head loss was recorded at design conditions. [Ref. 8.D.2]

Creating surrogate chips with exactly the size of the holes in the strainer (0.095 inch) is not practical. The transport velocity at the perimeter of the strainers is less than 0.1 fps which then decreases as the flow approaches the strainer surface. This indicates that chips greater than 1/64 inch (0.0156 inch) will sink as they approach the strainer debris interceptor based on NUREG/CR-6916, Hydraulic Transport of Coating Debris, December 2006. [Ref. 9.I]

Strainer qualification testing with a full sized module demonstrated that chips 1/64 inch and larger could not reach the strainer under design basis conditions. [Ref. 8.D.9]

Since the testing discussed above dispels any concern about chips blocking holes in the strainer, no further testing with chips alone (fiberless testing) was performed. The size distribution determined conservative for debris generation and transport is considered to be conservative for head loss testing.

For epoxy and phenolic coating debris specified as chips, the supplementary testing planned will use epoxy and/or Mylar chips similar in size and distribution to that in the debris generation and transport analysis.

3.h.4 Ongoing Containment Coating Condition Assessment Program

Coating failure research and the results of the nuclear coating survey regarding signs of degradation correlate to the extent that the majority of coating failures and signs of degradation can be attributed to undetected deficiencies that occurred at the time of coating application. These deficiencies are the major cause of coating deterioration during the coating systems' service life. [Ref. 4.F] CPNPP performs visual inspections each refueling outage to identify degradation and take corrective actions.

The acceptability of visual inspection as the first step in monitoring of Containment Building coatings is validated by EPRI Report No. 1014883, "Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level 1 Coatings," August 2007. [Ref. 4.E]

Monitoring of Containment Building coatings is conducted at a minimum, once each fuel cycle in accordance with CPNPP procedure EP-5.01 [Ref. 14.B] based on ASTM D 5163-05a, "Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant." [Ref. 12.C] Monitoring involves conducting a general visual examination of accessible coated surfaces within the Containment Building, followed by additional nondestructive and destructive examinations of degraded coating areas as directed by the plant Protective Coatings Specialist. Examinations and evaluations of degraded coating areas are conducted by qualified personnel as defined in CPNPP procedures as recommended by ASTM D 5163-05a. Detailed instructions on conducting coating examinations, including deficiency reporting criteria and documentation requirements are delineated in CPNPP procedures.

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

3.i.1 Housekeeping

CPNPP housekeeping control is governed by STA-607 (Ref. 14.G). Condition assessments and latent debris sampling (Ref.s 5.A, 5.B, 5.C, and 5.F) have shown the station controls and practices to be adequate to maintain the latent debris source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid.

Monitoring of containment conditions continue as described in Section 3.d.

3.i.2 Foreign Material Exclusion Program

CPNPP foreign material exclusion programmatic controls are governed by STA-625 (Ref. 14.N).

Condition assessments and latent debris sampling (Ref.s 5.A, 5.B, 5.C, and 5.F) have shown the station controls and practices to be adequate to maintain the latent debris source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid.

Monitoring of containment conditions continue as described in Section 3.d.

3.i.3 Design and Configuration Control

Design control procedure ECE-5.01, Design Control Program, was revised to require an emergency sump performance impact assessment for design changes inside containment.

Pertinent design specifications were revised to clearly identify material requirements for insulation, tapes, labels, aluminum, etc., to assure configuration control in accordance with STA-699, Configuration management program.

These procedures and specifications are adequate to maintain the latent debris source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid.

3.i.4 Maintenance

Maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65 by STA-606, Control of Maintenance and Work Activities.

In addition, maintenance in containment in Modes 1 to 4 is controlled by STA-620, Containment Entry.

These programmatic controls have been adequate to control materials and activities that could significantly affect emergency sump performance for the new strainers given their robust design and performance. Enhancements to these and related programs are being considered in close out activities associated with GSI-191 (Ref. 3.J).

3.i.5 Design and Operational Refinements

The suggested design and operational refinements given in the guidance report (GR Section 5) and SE (SE, Section 5.1) are addressed as follows.

There were no insulation change-outs in the containment to reduce the debris burden at the sump strainers. Insulation on Unit1 steam generators was changed from the original Diamond Power RMI to Transco RMI. However, no credit for the reduction in insulation debris was taken.

No actions were taken to modify existing insulation (e.g., jacketing or banding) to reduce the debris burden at the sump strainers.

Modifications were made to reduce the debris burden at the sump strainers as described in Sections 3.j and 3.l. These modifications optimized debris transport to the inactive sump under the reactor vessel during pool fill. They also reduced debris transport to the strainer.

Actions were taken to modify and improve the containment coatings program as described in Section 3.h.

Section 3.j Screen Modification Package

Plant hardware modifications, developed in response to issues identified in GL 2004-02 (as described in Ref. 2.A), are installed in CPNPP and are actively supporting compliance with the regulatory requirements for long term cooling following a design basis loss of coolant accident.

Hardware modifications include the following.

> ECCS sumps screens were replaced with new strainers increasing the effective surface area from 200 square feet to almost 4000 square feet per emergency sump. The new strainers are contained within a one foot tall solid debris interceptor which will significantly reduce the quantity of debris which could reach the strainers. Unit 1 was completed during 1RF12 in the Spring of 2007. Unit 2 was completed during 2RF09 in the Fall of 2006. Modifications which divert significant water and debris from entering the recirculation pool near the strainers were completed in December of 2007. The design approach is to maximize the capability of the strainer while minimizing the debris load to the extent practical.

> The Refueling Water Storage Tank (RWST) Low-low set point and the RWST switchover procedure were revised to support the strainer modification. The Refueling Water Storage Tank to Containment Spray Isolation valves were replaced to reduce closing time for switchover from injection to recirculation. Control board instruments, controls and alarm were modified to support the setpoint change and enhance the operator interface for ECCS and spray switchover.

> Various modifications were made to reduce recirculation water holdup volumes and to assure that blockage would not occur in critical areas such as the refueling cavity. These modifications are described in Section 3.l, Upstream Effects.

These modifications increase the minimum post accident flood levels for Large Break LOCA from 4 feet to over 5 feet resulting in a corresponding increase in net positive suction head (NPSH) margin for any pump taking suction off the sumps.

3.j.1 Major Features of the Original Sump Screen Design

The original sump screens were part of a structure over 6 feet - 3 inches tall and would not have been submerged at the previous minimum LOCA water levels. The previous minimum water level for Large Break LOCA was 4 feet [Elevation 812'-0"]. The effective (wetted) surface at that depth was approximately 200 square feet. The screens consisted of a fine screen, a coarse screen and a trash rack.

Picture P-3.j.1-1 (Attachment A) is an external view of an original sump screen showing the structure.

The containment floor is located at el. 808'-0". The centerlines of the two ESF Recirculation Sump pits are located approximately 45 apart in the annular region between the secondary shield wall and the containment wall. Each ESF train has a dedicated recirculation sump pit whose arc matches that of the containment walls. Dimensions of each pit are approximately 14' long (centerline of arc) X 5 '-5" wide X 6'-0" deep. The 16" ESF recirculation suction pipes are located in the pits in a slightly sloped orientation, terminating with a 24" suction cone opening. The centerline of the recirculation suction piping is at el. 804'-4 15/16" (approximately 3.5 ft. below containment floor elevation). A vortex suppressor, located within the sump, is provided for each suction pipe.

Picture P-3.j.1-2 (Attachment A) is a plan view of the sumps and suction piping. There are two sumps - One for train A ECCS and Containment Spray. One for train B ECCS and Containment Spray.

Picture P-3.j.1-3 (Attachment A) is an elevation view of the sumps and suction piping.

Picture P-3.j.1-4 (Attachment A) is an internal view of an original sump screen showing the fine mesh screen and the sump pit.

Picture P-3.j.1-5 (Attachment A) is a view of a sump, a vortex suppressor and suction piping.

Picture P-3.j.1-6 (Attachment A) is a close up view of an original screen. The fine screen openings were a maximum of 0.115 inches.

Pictures P-3.j.1-1 through P-3.l.1-6 (Attachment A) show the original sump screens.

The design of the original sump screens and vortex suppressors, in accordance with Regulatory Guide 1.82 Revision 0 [Ref. 9.F], was proven by full scale testing.

3.j.2 Major Features of the Sump Strainer Design Modification.

In anticipation of GSI-191 analysis showing that the original sump screen would be inadequate, CPNPP teamed with the Strategic Teaming and Resource Sharing (STARS) participants; Callaway, Comanche Peak, Diablo Canyon, Palo Verde, STP and Wolf Creek to request proposals for new strainers from qualified vendors.

In collaboration with the STARS team, CPNPP engineering evaluated six proposed strainer designs based on the following criteria:

1) adaptability of the design to specific plants,
2) constructability and maintainability,
3) flexibility (ability to increase or decrease sump screen area),
4) potential to minimize risk due to regulatory uncetainty, and
5) cost

CPNPP contracted with Performance Contracting, Inc. (PCI) to provide a qualified Sure-Flow® Suction Strainer specifically designed for CPNPP in order to address and resolve the NRC GSI-191 ECCS sump performance issue.

A passive strainer design was selected over an active strainer design because of concerns for constructability and maintainability as well as for downstream effects. Active approaches such as backflushing, screen cleaners, backup strainer banks which could be valved in if needed, were considered but not pursued due to the required Generic Letter 2004-02 schedule for the design and installation of new strainers.

The new strainers were specified to maximize the surface area employing a robust, modular design installed withing the existing screen structure. The specification requires the strainers to be designed for a minimum of 2 feet of water above El. 808' at the start of ECCS switchover and a minimum of 4.4 feet of water at the initiation of containment spray switchover.

CONSERVATISM - The structural requirements specified for the new strainers required design for a differential pressure of 14 feet of water (see Section 3.k.1) to account for the maximum flood level and NPSH margin available.

Two sump suction strainers per unit, each with nominal surface area of 3947 ft^2 were design to meet the specified requirements. [Ref. 8.A.1]

RAI 21 Each module contains 7 stacked disks 42 inches tall and has a surface area of over 100 ft^2. Four banks of nine modules each are connected to a plenum box which sits on a cover over the sump pit which also supports two of the banks of strainer modules. Pictures P-3.j.2-5 and P-3.j.2-6 illustrate the strainer and interceptor layout. The sump pit is self venting through the strainers and there is no venting to the containment above the top of the strainers.

Picture P-3.j.2-1 (Attachment A) shows a shop assembly of one strainer. Each strainer was fully assembled in the shop prior to shipment and again upon receipt at the plant before installation.

The existing screens and trash racks were scrapped and the new strainers were installed interior to the original structure.

RAI 17 Pictures P-3.j.2-2, P-3.j.2-2a, P-3.j.2-3, and P-3.j.2-4 (Attachment A) are plant views of new strainers, the debris interceptors, and the trash racks post installation. Pictures P-3.j.2-5 and P-3.j.2-6 illustrate the location of the debris interceptor in relation to the strainer layout. Each strainer is enclosed on three sides by the one foot tall solid debris interceptor which functions as a tall curb for tumbling debris. A solid panel (P-3.j.2-6 and P-3.j.3-8) was provided on the outboard ends to divert high velocity water from direct impingement on the strainer array.

RAI 9 The function of the debris interceptor during washdown and pool fill (Section 3.e) is to prevent preferential flow towards the sumps during the initial pool fill during the sheeting phase. Once the Elevation 808' floor is covered and water rises, the preferential flow will be away from the sumps and towards the inactive sump under the reactor vessel.

Trash racks are not required for this design; however, trash racks with 6 inch by 6 inch spaced bars were provided on two sides to protect the strainers from damage during outages. The side towards the containment liner is open.

The nominal hole size of 0.095 inches was specified for the perforated plate which is smaller than the 0.115 inches for the original screens. [Ref. 8.A.1]

The top of the strainer disks is 45 inches above the floor. To ensures the strainers are fully submerged during full recirculation for all design basis accident scenarios, the RWST setpoints and RWST switchover procedures were changed. The RWST to CSS Isolation Motor Operated

Valves were changed from slow closing gate valves to fast closing butterfly valves. See P-3.j.3-1 for the MOV Modification.

These changes are described in detail in License Amendment 129 [Ref. 2.C.1].

The containment flooding analysis has been revised to reflect all of the plant modifications. At the completion of switchover from injection from the RWST to recirculation from the sump for ECCS and CSS, the minimum water level is:

> 4.5 ft. for small break LOCA
> 5.0 ft. for large break LOCA
> 4.6 ft.for MSLB

[Ref. 7.F.17 and 7.A.1]

The key and unique design feature of the Perfomnance Contracting, Inc. (PCI) Sure-Flow® Suction Strainer is the flow control design of the core tube which assures that the flow through each strainer module is essentially equal. The top of the core tube is less than 2 ft. above the floor. The minimum flood level at the initiating of ECCS switchover is greater than 2.0 ft. above the floor [Ref. 7.F.17]. Switchover is complete within 25 minutes. Testing was performed on the prototype strainer to show that the strainer head loss and vortexing would be acceptable during the flood-up transient. [Ref. 8.D.2]

In addition, an analysis of the flood up transient for the sump strainers with the debris interceptors was performed to verify that the emergency sump pit and strainers would be full and flooded to greater than two feet at the initiation of ECCS recirculation. [Ref. 8.B.7]

3.j.3 Other Modifications Related to the Sump Strainer Modification.

RAI 11 In addition to modifications described in Section 3.l, Upstream Effects, the following modifications were made to minimize debris introduction and turbulence near the strainers.

- RWST motor operated isolation gate valves were replaced with faster closing butterfly valves. [P-3.j.3-1] This was required for the RWST setpoint change described in Section 3.j.2 above.

- An equipment drain near the strainers was capped to reduce local turbulence due to back flow. [P-3.j.3-2]

- Drains in the curb around the normal containment sump were capped to reduce local turbulence due to back flow. [P-3.j.3-3]
- The floor grating and seismic gap in the floor at Elevation 832' above the strainers were covered with flashing to divert water and debris and reduce local turbulence. [P-3.j.3-4, -5, -6, and -7]
- A solid panel to divert higher velocity water from impinging on the strainers. [P-3.j.3-8]

3.k Sump Structural Analysis

The objective of the sump structural analysis is to verify the structural adequacy of the sump strainer including seismic loads and loads due to differential pressure, missiles, and jet forces. The CPNPP structural analyses are based on the technical requirements and design input in Specification CPES-M-2044 ([REF. 8.A.1] "Emergency Sump Suction Strainers"). The structural analyses for the sump strainers and results are provided by PCI ([REF. 8.C.1] "Structural Evaluation of the Emergency Sump Suction Strainers").

3.k.1 Design Requirements

Classification

The new strainers are designed and analyzed as Seismic Category I equipment as described in FSAR Chapter 3.7B.3.

Codes and Standards

The strainers are not pressure retaining components. The design methods of AISC (3.k.4.a) were used for the design of structural components. Since the AISC does not address designs with stainless steel, supplemental input was obtained from N690-1994 (3.k.4.b).

For the perforated plates, the AISC does not provide any design guidelines for plates with our-of-plane pressure loads and closely spaced holes. Therefore, the equations provided by ASME (3.k.4.c) were used to calculate the stresses in the perforated sheet metal.

The strainer also has several components made from thin gage sheet and cold formed stainless steel. ASCE (3.k.4.d) 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 described herein were used. This is further supplemented by the AISI (3.k.4.e) where the ASCE Specification does not provide specific guidance. Finally, guidance is also taken from AWS (3.k.4.f) as it relates to the qualification of stainless steel welds.

Design Input

<u>Seismic Input</u>

The response spectra used are for the containment building basement at EL 808'-0". Being passive equipment that is primarily a bolted assembly, the damping used was 4% and 7% for OBE and SSE analyses, respectively. The seismic acceleration response spectra are summarized in Table 3.k-1.

Process Fluid Input

The design input for the process fluid used in the design and qualification of the new sump strainers is provided in Table 3.k-2.

Material Input

All steel plates and shapes are fabricated from Type 304 stainless. The materials were provided in accordance with a number of ASTM Specifications such as A-240, A-312 and A-493. The lower bound material properties associated with the ASTM A-240 were used in the design and qualification. The material properties at the maximum process fluid temperature were obtained from the ASME B&PV Code (3.k.4.h), and are provided in Table 3.k-3.

The tension rods are fabricated from ASTM A-276, Type 304, Grade B material. The material properties for the accident condition were computed using the same reductions as applied for Condition A materials, and are provided in Table 3.k-3.

Other material property input used in the design and qualification analyses are provided in Table 3.k-4.

All welding was performed with ER308 or ER308L electrodes with a minimum tensile strength of 75 ksi (3.k.4.f).

Design Loads

The following loads were considered in the design of the strainers.

Dead Weight (WT)

This includes the weight of all elements of the sump strainer in a dry condition. The sump strainers do not provide structural support to any other plant components.

Live Load (LL)

This is the possible additional load acting on the sump strainer during refueling outages only. The Live Load includes rigging reactions at lifting points or a smeared load of 100 psf.

Weight of Debris (WD)

This is the amount of mixed debris (i.e., fibers, coatings, etc.) based on the plant specific debris loading that could be theoretically transported to and deposited on the sump components. The amount of mixed debris that would settle on a given strainer module was based on bounding test data. The weight of debris was included with the vertical dead weight when computing the vertical seismic responses. The maximum amount of mixed debris on a given strainer module will not exceed 55 lbs. In addition to the theoretical debris that could act on the strainer modules, excess debris that is not captured by the modules would settle in the area immediately beneath and adjacent to the modules. The theoretical debris weight that would bear on the cover plate due to debris settlement will not exceed 827.1 lbs, or 10.43 lbs/ft^2.

During normal operating conditions there will be no debris on the sump strainers.

Differential Pressure (DP)

This is a static pressure load across the perforated plate during accident conditions when the strainers are covered with debris. This is conservatively based on the maximum allowable head loss (i.e., pressure drop) across the debris covered strainers and the cover plate plus the maximum hydrostatic pressure due to the depth of the water. The differential pressure used in the design qualification was 14 feet of water (8.83 ft pool depth plus 5 ft of allowable head loss rounded up).

Note that the Comanche Peak new sump strainer does not include any capability to back flush the strainers. Thus, the differential pressures will always be acting inwards on the strainer modules and downwards on the sump pit cover plates.

During normal operations, including periods of containment integrity pressure testing, the fully vented sump strainer design precludes any differential pressure stresses from occurring.

Seismic Loads

A response spectra analysis was performed to analyze the seismic inertia loads. The seismic loads included both the seismic inertia loads associated with the strainer metal mass and the hydrodynamic effect.

The hydrodynamic effect includes both sloshing and inertial effects of water with a full debris loading associated with the strainer modules being submerged in the post-accident pool. An analysis of the seismic induced sloshing loads for the Prairie Island strainers was used as the basis for not explicitly analyzing it for Comanche Peak. The Prairie Island analysis concluded that the seismically induced sloshing loads were negligible (5 lbs per module). The critical parameters for the comparison analysis of the two PWR plants were the size of the containment, the magnitude of the ground motions, and the size of the modules. Although there are slight differences between the values of the parameters used in the Prairie Island analysis compared to the corresponding values associated with Comanche Peak, these differences would not result in a different conclusion (i.e., sloshing loads are insignificant in comparison to other seismic loads). The conclusion of the comparison with Prairie Island was that the results were applicable to Comanche Peak. Furthermore, the conservatism in the hydrodynamic mass determination more than offsets any loads resulting from a sloshing of the water inside containment.

The strainers are subjected to seismic accelerations in the submerged condition. As such, there will be a hydrodynamic mass effect that must be considered. In addition to the steel mass of the strainer being subjected to seismic accelerations, the mass of the water enclosed by the strainer and some portion of the mass of the water surrounding the strainer will also be accelerated. Reference (3.k.4.g) provided the formulas to determine the hydrodynamic mass, or added mass, for various cross sections of the sump strainer design. The hydrodynamic mass is different in each direction of seismic motion because the profile of the strainer is different in each direction. The results of the analysis determined that the following water weights were required to be added to each strainer module.

$Mass_X$ = 1,596 lbs (axial direction)

$Mass_Y$ = 736 lbs (vertical direction)

$Mass_Z$ = 882 lbs (lateral direction)

The seismic analysis of the strainers was performed with the mass of the steel elements adjusted to include the weight of debris and the added hydrodynamic mass.

Temperature - Accident (T_A)

There are no significant stresses due to the restraint of thermal expansion. The individual strainer modules are basically free to expand without restraint due to the designed gaps built in to every connection. The floor mounting angles and sump cover plates have insignificant loads due to restrained thermal growth due to the use of slotted bolt holes with expansion gaps in the design. For the impact on material properties, the design accident temperature was assumed to be the maximum process fluid temperature of 269° F even though the required maximum temperature was 265° F.

Pipe Break (Y_m, Y_r, Y_j)

Loads associated with pipe whip, jet impingement and missile impacts associated with LOCA and secondary high-energy line breaks are not credible for the new sump strainers. The strainers are located outside of the loop rooms where they will not be exposed to any dynamic effects of LOCA pipe breaks. Furthermore, the new sump strainers were installed under the protective structural steel cover that formed the roof of the old sump design. A large opening steel rod mesh was provided to further protect the strainers from accidental physical damage during refueling outages and from buoyant debris following a postulated pipe break.

Design Load Combinations

The following loading combinations were considered in the design and qualification of the new sump strainers.

LOADING CONDITION	COMBINATION	ALLOWABLE
(1a) Normal Operating	WT	1.0 S
(1b) Normal Operating (outage)	WT + LL	1.0 S
(2) Operating Basis Earthquake	WT + DP + WD + OBE	1.0 S
(3) Safe Shutdown Earthquake	WT + DP + WD + SSE	1.6 S

By inspection, load combination equation number 2 will bound the results from load combination equation 1.a. Load combination 1.b provides localized stresses through load paths that are not used when installed, such as lifting lugs, and is therefore uniquely bounding for a few components.

The allowable, S, is the AISC allowable unless supplemented by another source. The Load Combination 3 AISC based allowable stress of 1.6 S is limited to 90-percent of yield for both normal and shear stresses.

The perforated plates are evaluated by the equations of Article A-8000 (3.k.4.c). Note that Article A-8000 refers to Subsection NB for allowable stresses which are defined in terms of stress intensity limits, S_m. NB-3220 provides stress limits, S, for the primary membrane, and primary membrane plus bending. Based on Table NC-3321.1 (3.k.4.l) and Article A-8000 (3.k.4.c), the allowable stresses for the perforated plate are provided below.

LOAD CONDITION	STRESS TYPE	ALLOWABLE STRESS
Normal/Upset	Primary Membrane	1.0 S
	Primary Membrane + Bending	1.5 S
Emergency/Faulted	Primary Membrane	min(1.2 S or 1.0 S_y)
	Primary Membrane + Bending	min(1.8 S or 1.5 S_y)

3.k.2 Structural Analysis

The analysis of the strainer modules was performed with the aid of two computer programs, GTSTRUDL and ANSYS. Both GTSTRUDL and ANSYS are general purpose finite element programs.

The structural analysis of the strainer modules was performed with GTSTRUDL, and took advantage of the similarity between modules. The modules are essentially identical with the only difference being the hole sizes in the core tube. Therefore, only one strainer module pair (side-by-side on the same angle track) was required to be analyzed. Each module pair is independently supported and can therefore be analyzed as individual units. The modules are connected with thin gauge stainless steel sleeves that are used to prevent debris from entering the system between adjacent in-line modules. This connection permits relative motion in the axial direction as the core tube can slide relative to the stainless steel sleeves. The sleeves can transfer shear loads but not moments, therefore, the analysis considers the scenario when adjacent in-line module pairs are in phase with one another (student body motion in axial direction with all modules moving in the same direction) and when adjacent module pairs are 180^{O} degrees out of phase (adjacent units moving in opposite axial directions). Both phase conditions were evaluated to ensure that the bounding solution was analyzed. The worst case module pair is the end module pair because these modules have the highest hydrodynamic mass and also have the largest holes in the core tubes.

Four different GTSTRUDL seismic models are used to evaluate the strainer modules. All four models include a pair of strainer modules, but use different support configurations to represent the differences in the way the modules respond to dynamic loads. The first model is for the modules over the sump pit which are anchored at the end with Belleville springs. The flexibility of the sump pit cover plate is considered in this model using a combined section as the two modules respond as a pair to dynamic loads. The second model is identical to the first, except that at the ends the angles are connected to clip angle supports which are welded to the embedded angle and adjacent baseplates. The third model is for the modules that are over the concrete. In this model, the strainer modules themselves are identical to the first two models, however in this model the angle iron tracks are supported by eight expansion anchor bolts with the anchor points modeled into the angles. Also in this model, the two strainer modules are supported independently and do not act together dynamically. The three previous models conservatively used the hydrodynamic forces of an end module. The fourth model is the end module strainer which is supported over the sump pit on one side, and anchored to the embedded angle at the lip of the sump pit on the other. This end module controls over the end module supported over concrete because of the flexible cover plate on one side. This end model has an additional force not required in the previous three models to account for the differential pressure across the end cover of the core tube.

Most of the member properties used in the four structural models are defined using standard shapes available in GTSTRUDL. Those that could not be represented by the standard shapes, such as the core tube and edge channels were represented by equivalent member sections. Appropriate member end releases were used in order to simulate the anticipated behavior of connections.

The stresses in the perforated plate face disks for seismic loadings were computed using the ANSYS finite element program. Two cases were evaluated by ANSYS.

Case 1 reflects the scenario where the perforated plate bends inwards into the internal wire stiffeners. In this case, the perforated plate is supported at the four outer tension rods and around the core tube by the gap disk. Along the edges of the disk, the edge channels are modeled in as flexible supports.

Case 2 reflects the scenario where the disk face bends outward and pulls away from the internal wire stiffeners. In this case, the disk face is supported at the four outer tension rods and around the core tube by the seven inner tension rods. Along the edges of the disks, the edge channels are modeled in as flexible supports. In addition to the edge channels, the external radial stiffeners are modeled in as flexible supports.

The stresses in the inner gap were also determined using the ANSYS finite element program to take advantage of the added strength associated with the curvature of the inner gap. The analysis was initially performed for another plant whose configuration is not identical to those for Comanche Peak. The model was developed for a gap diameter of 18.48-inches and a thickness of 0.0478-inches (18 ga.). The Comanche Peak gap diameter is 17.875-inches and a thickness of 0.0959-inches (16 ga.). In addition, the Comanche Peak inner gap uses seven tension rods used for support versus just four used in the analysis. The use of the existing analysis was judged to be conservative in that a smaller gap diameter with additional support points will result in lower stresses.

The inner gap model includes the full 360-degrees of the gap plate. The cross section is just a thin flat plate, modeled as an equivalent plate to account for the perforations. The model is supported at four discrete points along the circumference at the inner rod locations. One way supports are used such that they only restrain the plate from displacing inward, but offer no resistance if the plate wants to pull away from the rods. Three cases of unit load pressure (1 psi) were applied. Case 1 is for all the pressure in the vertical direction. Case 2 is similar, but with the pressure acting in the lateral direction.

Case 3 is for the differential pressure that is acting radially inward. A fourth combined case was run with the initial guesses for the actual pressures in each direction. The ANSYS results were then scaled up by the worst case increase from any of the three load cases.

In addition to bending stresses calculated by ANSYS, buckling of the inner gap ring was also evaluated. The buckling evaluation was performed based on Section 7.3 through 7.6 of Timoshenko's book on elastic stability (3.k.4.m).

Since the inner gap ring will be supported at the tension rods and periodically between each tension rod by tabs off of the strainer disks, the buckling mode of the gap disk will reflect the higher modes of buckling for the circular ring discussed in Section 7.3. Due to symmetry, the equations for the circular arch under uniform pressure discussed in Section 7.6 will have the same results as the circular ring from Section 7.3. Since the buckling of this arch depends on the inextensional deformation of the arch, the buckling mode resembles that of the second mode of buckling of a column, with an inflection point in the center. The critical buckling pressure required to case the inner gap ring to buckle for the maximum support spacing was computed by equation 7-21 of Reference 93.k.3.m) and determined to be 15.51 psi. The critical buckling pressure was then reduced by the AISC factor of safety of (23/12) used for column buckling from Section 2.4 of Reference (3.k.4.a).

3.k.3 Summary of Results

The new sump strainers were conservatively evaluated for the postulated loads associated with OBE, SSE, and accident conditions including flooding with debris and suction head losses. The structural elements were evaluated for the combined postulated loads and compared to acceptance criteria that maintained the stresses within the elastic region. The perforated plate was evaluated by methods consistent with the ASME Boiler & Pressure Vessel Code for tube sheets.

The results of the qualification analyses for the new sump strainers are summarized in Table 3.k-5. The table provides the critical attribute actual (i.e., force, stress, etc), the corresponding allowable, and the interaction ratio (IR). The interaction ratio is the actual divided by the allowable. Thus, any interaction ratio less than or equal to 1.00 indicates conformance with the design requirements.

The conclusion of the structural analyses is that the new sump strainers are qualified as Seismic Category I, Nuclear Safety Related equipment, and that they are structurally capable of performing their intended design function.

3.k.4 References

a. American Institute of Steel Construction (AISC), "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings", February 1969, with Supplements 1, 2 and 3.

b. American National Standard ANSI/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities."

c. American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section III, Division 1, Appendices, Article A-8000, "Stresses in Perforated Flat Plates," 1989 Edition, No Addenda.

d. American Society of Civil Engineers (ASCE) Standard SEI/ASCE 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members."

e. American Iron and Steel Institute (AISI), "Specification for the Design of Cold-Formed Steel Structural Members," 1996 edition.

f. American National Standard ANSI/AWS D1.6:1999, "Structural Welding Code - Stainless Steel."

g. Blevins, Robert D., "Formulas for Natural Frequency and Mode Shape," Van Nostrand Reinhold, 1979.

h. American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section II, Part D, Material Properties, 1998 Edition, through 1999 Addenda.

i. Avallone, and Baumeister, "Mark's Standard Handbook for Mechanical Engineers," 9th Edition, McGraw-Hill.

j. Robertson, John A. and Clayton T. Crowe, "Engineering Fluid Mechanics," 2nd Edition, Rudolf Steiner Press, Library of Congress Catalog Number 79-87855.

k. Moran and Shapiro, "Fundamentals of Engineering Thermodynamics," 4th Edition, John Wiley & Sons.

l. American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section III, Division 1, Subsection NC, 1989 Edition.

m. Timoshenko, Stephen P. and James M. Gere, "Theory of Elastic Stability," 2nd Edition, McGraw-Hill.

3.k.5 Tables

Table 3.k-1: Seismic Spectra Input Summary

EVENT	DAMPING (%)	DIRECTION	PEAK OF SPECTRA (g)	ZPA (g @ 39.5 Hz)
OBE	4	North-South	0.527	0.115
OBE	4	Vertical	1.141	0.183
OBE	4	East-West	0.536	0.112
SSE	7	North-South	0.668	0.210
SSE	7	Vertical	1.413	0.327
SSE	7	East-West	0.660	0.205

Table 3.k-2: Process Fluid Conditions

PROCESS FLUID CONDITION	NORMAL	ACCIDENT
Working Fluid	Air	Borated Water
Max Sump Water Level	N/A	EL 816.83 ft (8.83 ft above basement floor elevation.)
Fluid Temperature	60°F to 120°F	265°F (max)
Max Head Loss Allowed	N/A	3.0 feet (RHR @ T = 0 minutes) 5.0 feet (CSS @ T = 25 minutes)

Table 3.k-3: Material Properties

ASTM A-240 Type 304	@ 70°F	@ 269° F*
Modulus of Elasticity	E = 28,300 ksi	E = 27,200 ksi
Yield Strength	Sy = 30.0 ksi	Sy = 23.1 ksi
Ultimate Strength	Su = 75.0 ksi	Su = 67.7 ksi
Allowable Stress	S = 20.0 ksi	S = 19.2 ksi

ASTM A-276 TYPE 304 Gr. B		
Yield Strength	Sy = 100.0 ksi	Sy = 77.0 ksi
Ultimate Strength	Su = 125.0 ksi	Su = 112.8 ksi

* Note the reduced material properties at 269°F were used instead of the required 265°F. The difference in the material properties due to the 4°F variance is trivial and in the conservative direction (i.e., reduced values).

Table 3.k-4: Other Material Properties

PROPERTY	VALUE USED	REFERENCE
Density of Stainless Steel	501 lbs/ft^3	(3.k.4.i)
Poisson's Ratio	0.305	(3.k.4.i)
Density of water @ 20°C	62.4 lbs/ft^3	(3.k.4.j)
Density of water @ 269°F**	58.3 lbs/ft^3	(3.k.4.k)
Mean Coefficient of Thermal Expansion of Stainless Steel (70°F to 269°F)	9.14E-06 in/in/°F	(3.k.4.h)

** Note the decreased density of water at 269° F compared to 265° F has negligible increase to the water masses calculated.

Table 3.k-5: Summary of Analysis Results	LOAD CASE	ALLOWABLE STRESS OR LOAD	MAXIMUM STRESS OF LOAD	IR
Perforated Plate	OBE	28.8 ksi	25.1 ksi	0.87
	SSE	34.56 ksi	29.73 ksi	0.86
Wire Stiffener (*OBE allowable of 1.0 S was used)	SSE	17.32 ksi*	16.90 ksi	0.98
Weld of Radial Stiffener to Core Tube	OBE	0.58 k/in	0.55 k/in	0.95
	SSE	0.72 k/in	0.65 k/in	0.91
Weld of Seismic Sleeve to Debris Stop	OBE	1.73 k/in	1.57 k/in	0.91
	SSE	2.17 k/in	1.97 k/in	0.91
Module-to-Module Latch Connection	OBE	219 lbs	199.5 lbs	0.91
	SSE	328 lbs	290.5 lbs	0.89
Angle Iron Tracks on Concrete	OBE	F_A= 13.86 ksi	f_N= 13.47 ksi	0.97
		F_V= 9.24 ksi	f_V= 1.43 ksi	
	SSE	F_A=20.79 ksi	f_N= 18.45 ksi	0.89
		F_V= 11.55 ksi	f_V= 2.24 ksi	
End Module Angle Iron Tracks on Concrete	OBE	F_A=13.86 ksi	f_N=13.28 ksi	0.96
		F_V= 9.24 ksi	f_V= 3.67 ksi	
	SSE	F_A=20.79 ksi	f_N=15.85 ksi	0.76
		F_V= 11.55 ksi	f_V= 4.38 ksi	
Expansion Anchors to Floor	OBE	T_A =1698 lbs	T=1113 lbs	0.51
		V_A =3986 lbs	V=316 lbs	
	SSE	T_A =1698 lbs	T=1583 lbs	0.91
		V_A =3986 lbs	V=423 lbs	
Sump Pit Cover Plate	OBE	17.3 ksi	15.83 ksi	0.92
	SSE	20.79 ksi	16.54 ksi	0.80
Weld of Tee to Sump Pit Cover Plate	OBE	1.73 k/in	1.68 k/in	0.98
	SSE	2.17 k/in	1.71 k/in	0.80
Inner Gap Ring Buckling	DP	8.09 psi	6.07 psi	0.75

Section 3.l Upstream Effects

The objective of the upstream effects assessment was to evaluate the flowpaths upstream of the containment sump for holdup of inventory which could reduce flow to and possibly starve the sump.

The reactor cavity is an inactive sump below the elevation of the emergency sumps. It is addressed in Section 3.e.

The evaluation was performed under SMF-2001-002201 [Ref. 3.A]. Modifications were performed under SMF-2002-001952 [Ref. 3.B] and SMF-2005-003364 [Ref. 3.H].
The modifications based on the upstream effects evaluation assure 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.

3.l.1 Evaluation of Upstream Effects

The initial evaluation of upstream effects was documented in WES002-PR-02, Evaluation of Containment Recirculation Sump Upstream Effects for the Comanche Peak Steam Electric Station, Rev. 0 dated 8/17/05 [Ref. 7.C.1] as described in Letter Logged TXX-05162 dated September 1, 2005, RESPONSE TO REQUESTED INFORMATION PART 2 OF NRC GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" [Ref. 2.A]. The evaluation included review of design documents and verification by walk down for the various flow paths to the containment base slab, which is the location of the ECCS recirculation sumps.

3.l.2 Modifications to the Refueling Cavity Drains

As part of the upstream effects review, the refueling cavity drains were identified as a potential plugging point. These drains return a portion of the upper containment spray flow back to the lower volume of containment.

(1) Upender Area & Refueling Cavity Lower Internals Storage Area 4 Inch Drains:

Drain strainers for the two Refueling Cavity 4 Inch drains were designed and fabricated based on the design and qualification of the emergency sump strainers. The SF Drain Strainers were supplied by Performance Contracting Inc. (PCI) under Specification CPES-M-2044 [Ref. 8.A.1] as Seismic Category I equipment. The core tubes of the strainers are installed aligned with the drain cavities with the module assembly sitting on the liner floor. Two (2) guide pins pass through the drain cover plate to maintain orientation. Each strainer is supported by its own weight. Inherent in the design is a capturing mechanism that will not allow the strainer to move horizontally, and its weight will ensure it remains in place during an SSE event.

RAI 32 Drain strainers were selected rather than debris screens since the existing drain covers used during refueling has 3/4 inch holes and could be subject to blockage by fibrous debris during a DBA. As shown on P-3.1.2-1a, the design uses stacked disks of perforated plate with 0.095 inch holes to provide approximately 72.9 ft^2 of strainer surface area. Each one has a solid steel top to protect them from falling debris. The design is not vulnerable to blockage from large debris such as RMI or a LDFG blanket.

Upender Area Drainage - Maximum spray flow into the upender area (243 ft^2, 1.7% of upper containment) is 185 gpm. The perimeter of the area at the operating deck was modified to minimize any spray drainage from the surrounding area. Each drain strainer is 1.8% size of the emergency sump strainer. Since only a portion of the accident debris would be ejected into upper containment, the debris load on the drain strainer would be bounded by the debris load on the sump strainer. The refueling cavity holdup assumed in the minimum flooding calculation for the emergency sump assumed 2 ft of holdup (< 400 ft3) which is equal to 10.8 inches of submergence. The Clean Strainer Head Loss (CSHL) at 250 gpm is 0.042 ft. The 30 day debris laden head loss for the sump strainers is approximately 7.2 inches. Therefore, the drain strainer is qualified by comparison to the main emergency sump strainer.

<u>CONSERVATISM</u> - No credit was taken for the intervening Fuel Handling Bridge Crane or Refueling Machine over the upender area to reduce the debris load.

<u>CONSERVATISM</u> - No credit for the drain strainers were taken to reduce sump debris loads.

Pictures P-3.1.2-1 and P-3.1.2-3 (Attachment A) show a drain strainer before and after installation.

These strainers are administratively controlled. They may be removed during refueling outages in Modes 5 and 6 when the normal drain function is used. They are required to be installed in

Modes 1-4 when the 4" drains are also required to be open to containment.

(2) Refueling Cavity Lower Internals Storage Area 6 Inch Drains:

The main refueling cavity has two architectural drains which consists of open six inch pipes connecting the refueling cavity to the main area of containment. These drains are covered by a blind flange during refueling.

Refueling Cavity 6 inch Drain Debris Screens for the 6" dia. architectural drains were designed and fabricated in accordance with Seismic Category I requirements. These screens will prevent blockage by large debris. They will pass debris small enough to pass through the pipe without blockage. This design is not vulnerable to RMI or fibrous debris.

Pictures P-3.1.2-2 and P-3.1.2-3 (Attachment A) show a drain debris screen before and after installation.

These debris screens are administratively controlled. They are removed during refueling outages in Modes 5 and 6 when the drains are covered by a blind flange to enable filling of the refueling cavity. They are required to be installed in Modes 1-4 when the 6" drains are also required to be open to containment.

(3) Removal of pipe reducers at the end of refueling cavity drain pipe

Refueling Cavity 4 Inch drains are required to be open in Modes 1-4. Reducers had been installed to allow connection of hoses to the drains during outages. These reducers would limit outflow of water via this drain path.

The modification made to the existing refueling cavity drain from 4" x 2" reducer to 4" straight pipe with elbow as shown was made to maximize the drain flow. Removable fittings are provided for outages.

Picture P-3.1.2-4 (Attachment A) shows the drain pipe before and after modification.
The removable fittings are administratively controlled. They are removed during Modes 1-4.

3.1.3 Other Measures Taken to Mitigate Potential Choke Points and Water Holdup

Additional pinch points and water holdup volumes were identified which were evaluated and modifications were made to minimize water lost for recirculation.

(1) Wire Mesh Door Modification

Picture P-3.1.3-1 (Attachment A) shows the wire mesh door replaced by the door with six inch spaced bars.

(2) Reactor Vessel (RV) Head Stand Shield Wall Modification:

The shield wall is an NNS structure that has no structural function. The only function of the RV head stand shield wall is to provide a radiation barrier during the storage and cleaning of the head during a refueling outage. It has a floor drain interior to the wall. To assure that fibrous debris does not block drainage and hold up water, twelve (12) - 2 inch diameter holes were core drilled in the shield wall.

Each pair of 2" dia. holes is designed to be located behind the corresponding pedestal and the centerline of the holes are 3" above the floor surface. The configuration provides sufficient shielding during outages while the hole height location minimize the amount of contaminated water that could exit to the open area when outage personnel decon the area. This is consistent with ALARA.

Picture P-3.1.3-2 (Attachment A) shows the head stand shield wall modification.

(3) Toe Plate Modifications

Equipment hatches located at Elevations 905 and 860 were identified as major drain paths for containment spray on those elevations. These hatches are protected by handrails with toe plates. The toe plates were modified to be raised during Modes 1-4 to allow free drainage through the hatches.

Picture P-3.1.3-3 (Attachment A) shows a toe plate modification.
The toe plates are administratively controlled. They are raised during Modes 1-4.

(4) Roll Away Missile Shield Plat form Modification

The Roll Away Missile Shield (RAMS) Platforms were identified as possible water holdup due to solid floor and toe plates. The Unit 1 RAMS was removed by an unrelated modification in 1RF12. The checkered plate floors of the Unit 2 RAMS platforms were drilled with 1-1/4" holes to enable drainage of spray water.

Picture P-3.1.3-4 (Attachment A) shows the RAMS platform modification.

(5) Ventilation Exhaust Modification

The CRDM Cooling Fans were identified as possible water holdup due to vertical exhausts. The Unit 1 fans were removed by an unrelated modification in 1RF12. The Unit 2 fans were retrofitted with hoods to prevent ingestion of spray water.

Picture P-3.1.3-5 (Attachment A) shows the Unit 2 ventilation exhaust modification.

(6) Whip Restraint Modification

A number of pipe whip restraints were oriented such that spray water could be trapped. Flashing was added to divert spray water from accumulating in the restraints.
Picture P-3.1.3-6 (Attachment A) shows a whip restraint before modification. Picture P-3.1.3-7 (Attachment A) shows that whip restraint after the modification.

(7) Tube Steel Newell Caps

A number of vertical tube steel beams were identified which had not been covered by Newell caps in accordance with specifications.

Picture P-3.1.3-8 (Attachment A) shows four tube steel columns before modification. Picture P-3.1.3-9 (Attachment A) shows four columns after the modification.

3.1.4 Summary of Upstream Effects

The calculation of containment flood levels [Ref. 7.F.17] was revised in support of the above modifications to address the issues identified in the WES002-PR-02, Evaluation of Containment Recirculation Sump Upstream Effects for the Comanche Peak Steam Electric Station, Rev. 0 dated 8/17/05 [Ref. 7.C.1]. Modifications and analysis of upstream effects are complete. [Ref. 7.F.2]

Section 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.

Testing and analysis of downstream effects were completed in accordance with WCAP-16406-P-A, Evaluation of Downstream Sump Debris Effects in Support of GSI-191, [REF. 6.A] and the NRC Safety Evaluation [REF. 1.E].

3.m.1 Debris Ingestion

Debris ingestion calculations are documented in CN-CSA-05-65, Comanche Peak Units 1 and 2 GSI-191 Downstream Effects Debris Ingestion Evaluation [Ref. 7.E.5]

The purpose of this analysis is to support the overall effort to analyze the downstream effects of debris following LOCA by determining the quantity and size of debris which may pass through the containment sump screens and the concentration of this debris in the sump pool following a HELB for Comanche Peak Units 1 and 2. The results of this calculation note were used as input to other downstream evaluations.

In order to evaluate the impact of debris in the ECCS, an initial concentration of the debris in the sump fluid must be determined.

The quantity of debris in the recirculating fluid that passes into 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 ECCS and CSS.

Likewise, the mass concentration of debris in the recirculation fluid that passes into the sump is characterized in terms of parts per million (ppm). For downstream effects, this debris concentration (M_C) is defined as the ratio of the solid mass of the debris in the pumped fluid to the total mass of water that is being recirculated by the ECCS and CSS.

The debris source term for debris ingestion was taken from the results of the debris generation and transport analysis [Ref. 7.A.5] as shown in Section 3.e.

Note the following debris sources fail with a characteristic size of at least 0.125 inch. Since this dimension is more than 10% larger than the replacement strainer hole size of 0.095 inches (2.4 mm), these pieces will not pass through the replacement sump screen, and were not considered in the analysis:

- RMI large pieces
- Antisweat fiberglass larger than fines
- Lead blanket fiberglass larger than fines
- Unqualified Coatings 1/8" and larger
- Unqualified labels
- Tape
- Labels
- Tubing

<u>Conservatism</u> - Transport testing [Ref. 8.D.9] showed that no small RMI pieces would each the strainer. However, no credit was taken in the debris ingestion analysis.

<u>Conservatism</u> - Bypass testing [Ref. 8.D.9] and analysis [Ref. 7.A.14 and 7.A.15] showed that no coatings chips 1/64 inch and larger would bypass the strainer. However, no credit was taken in the debris ingestion analysis.

For the purpose of the calculation, the concentration provided assumes that 5% of the fibers will pass through the sump screen. This is conservatively based on Appendix B of Reference 9.N [Ref. 9.C] which shows that the sump screen will capture at least 96% of the fiber available, independent of the sump screen size. Fiber bypass testing and analysis was performed during strainer qualification testing [Ref. 8.D.7, 8.D.8, 8.D.9] and evaluated [Ref. 7.F.37]. It was concluded that the standard fiber bypass assumption was conservative and that the bypass test data would not be used in the debris ingestion calculation.

Particulate bypass testing and analysis was performed during strainer qualification testing [Ref. 8.D.7, 8.D.8, 8.D.9] and the bypass samples were evaluated. A specific coatings bypass test was performed with 6 mil chips based on observations in previous testing that the 100% transport of coatings is an overly conservative assumption. It was concluded that the standard bypass assumption was overly conservative and that the bypass test data would be used in the debris ingestion calculation. The bypass percentage for 6 mil chips was assumed to be 47.66% because only 47.66% of the debris placed upstream of the strainer penetrated the strainer initially.

Conservatism - In addition, the 6 mil chip debris bypass was shown to deplete with time (see page 24 of Attachment D); however, credit for decay was not taken in the analysis except where specifically noted below.

The following table provides the results of the debris ingestion calculation.

Primary Side Bypass Fraction, Break Volumetric and Mass Concentration Results [Ref. 7.E.5]

Debris	Screen Bypass Fraction	Volume carried through (ft^3)	Volume Concentration	Mass carried through (lb)	Mass Concentration (ppm)
Fibrous					
Antisweat Fiberglass	0.05	0.68	1.137E-05	1.63	0.45
Lead Blanket Fiberglass	0.05	0.02	2.842E-07	1.34	0.37
Min-K Fibrous	0.05	0.03	5.792E-07	0.08	0.02
Lead Wool Debris	0.05	0.01	1.797E-07	1.29	0.36
Latent Fibrous	0.05	0.50	8.358E-06	1.20	0.33
Total Fibrous					**1.54**
Particulate					
Min-K Particulate	1.0	0.04	6.911E-07	6.66	1.85
Latent Particulate	1.0	0.80	1.345E-05	136.00	37.82
Total Particulate					**39.67**
Coatings					
Acceptable Epoxy	1.0	2.12	3.544E-05	262.91	73.12
Acceptable CZ11	1.0	1.81	3.032E-05	376.00	104.57
Unqualified Epoxy (6 mil)	0.4766	13.58	2.270E-04	1352.60	376.17
Unqualified Epoxy (1/64)	1.0	23.94	4.001E-04	2383.94	662.99
Unqualified IOZ	1.0	80.09	1.339E-03	16834.20	4681.69
Unqualified Alkyd	1.0	1.35	2.257E-05	103.67	28.83
Total Coatings					**5927.36**
Totals		**124.97**	**2.089E-03**	**21461.53**	**5968.58**

3.m.2 Downstream Effects - Blockage (except for the reactor vessel)

Blockage evaluations for downstream components such as valves, orifices, heat exchangers, eductors, nozzles, etc. are documented in WES002-PR-01, Evaluation of Containment Recirculation Sump Downstream Effects for the Comanche Peak Steam Electric Station [7.C.2]

System flow paths were evaluated to identify components which could be exposed to recirculating debris and compare the size of the limiting flow passageways to the size of the debris that could enter the process fluid through the sump screen openings.

This analysis was performed for the original sump screens which had a maximum 0.115 inch opening in the wire screen mesh. This bounds the new sump strainers which have a nominal 0.095 inch holes in perforated plate.

Specifically, the maximum dimensions of particulate debris passing through a passive sump screen are evaluated as:

- The width of defomable particulates that may pass through the sump screen is limited to the size of the flow passage hole in the sump screen, plus 10%.
- The thickness of deformable particulates that may pass through the sump screen is limited to one-half the size of the flow passage hole.
- The maximum length of deformable particulates that may pass through the flow passage hole in the sump screen is equal to two times the diameter of the flow passage hole in the sump screen.
- The thickness and/or width and maximum length of non-deformable particulates that may pass through the sump screen is limited to the size of the flow passage hole in the sump screen.
- Based on a maximum flow passage hole for the replacement strainers being equivalent to that of the original screens (0.115 inches), the maximum debris size used in this evaluation is 0.23 inches for deformable particulate (two times strainer hole size) and 0.115 inches for nondeformable particulate.

No blockage or plugging issues for components required during a LOCA or MSLB were identified. The limiting components are ECCS throttle valves which are throttled to minimum final stem position greater than or equal to 0.24" open which is grater than 2 times the opening in the original screen..

In addition, blockage of mechanical seals and associated equipment (seal coolers and cyclone separators) for pumps is documented in EVAL-2001-002201-20-00, Evaluate mechanical seals on ECCS and CT Pumps for Leakage requirements and for the effect of failure of the seal and disaster bushing [7.G.16].

This evaluation used the same methodology as the above to evaluate for blockage of seal coolers and cyclone separators except that the new strainer design (0.095 inch holes) was used. No blockage or plugging issues for seal coolers or cyclone separators were identified.

3.m.3 Downstream Effects - Wear

Wear calculations and evaluations are documented in:

- CN-SEE-05-100, Comanche Peak Sump Debris Downstream Effects Evaluation for ECCS Equipment [7.E.1]
- CN-SEE-05-87, Comanche Peak Sump Debris Downstream Erosion Effects Evaluation for ECCS Valves [7.E.2]
- EVAL-2001-002201-24, Evaluate a scenario where debris laden containment sump water erodes the chemical injection eductors sufficiently to impact the Containment Spray Pumps. [7.F.38]
- EVAL-2001-002201-20-00, Evaluate mechanical seals on ECCS and CT Pumps for Leakage requirements and for the effect of failure of the seal and disaster bushing [7.G.16].

In order to evaluate the wear on the equipment within the ECCS and CSS recirculation flow paths, the wear models developed in WCAP-16406-P-A [6.A] and WCAP-16571 [Ref. 7.E.7] were used.

In Ref. 7.E.1, the Comanche Peak heat exchangers, orifices, and spray nozzles were evaluated for the effects of erosive wear for an initial debris concentration of 5968.58 ppm (Section 3.m.1 above) over the mission time of 30 days. The wear on all components is determined to be insufficient to affect the system performance, except for the CSS eductors, for which further evaluation was required.

The CSS eductors were evaluated by Comanche Peak Engineering [Ref. 7.F.38 and 7.F.39]. It was concluded that excessive wear on the eductors would not result in unacceptable impacts on pump run out or NPSHa.

For pumps, the effect of debris ingestion through the sump screen on three aspects of operability, including hydraulic performance, mechanical shaft seal assembly performance, and mechanical performance (vibration) of the pump, were evaluated. The hydraulic performance of the RHR and CS pumps was determined to not be affected by the recirculating debris. The mechanical performance of the SI pumps was determined to be affected by the recirculating sump debris. The SI pumps meet the acceptance criteria for wear for a maximum of 17 days, however, if the decay curve for the Unqualified Epoxy (6 mil) debris is applied, the pumps meet the acceptance criteria for wear for the mission time of 30 days. The mechanical perfomance of the CC pumps was determined to not be affected by the recirculating sump debris.

Ref. 7.E.2 evaluated the valve wear due to erosion, based on the concentration and component make-up of the sump debris mix at Comanche Peak Units 1 and 2 and evaluated the possible sedimentation of debris.

The only exceptions taken to the methodologies presented in WCAP-16406-P-A and NEI 04-07, (Ref.s 6.A and 4.A) were the use of the coatings bypass and decay for 6 mil chips as described above and the use of WCAP-16571 for wear from paint chips.

All of the throttle valves and valve inserts passed the wear evaluation. Using conservative minimum flow rates, all of the critical valves passed the sedimentation evaluation.

In addition to the above, mechanical seals were evaluated as documented in EVAL-2001-002201-20-00, Evaluate mechanical seals on ECCS and CT Pumps for Leakage requirements and for the effect of failure of the seal and disaster bushing [7.G.16]. This evaluation was performed with assistance from seal expert for the seal vendors.

All of the ECCS pumps have a mechanical shaft seal with a primary seal that ensures water in the system does not leak out of the pump when it is in standby or during normal operation. The primary seal has one face made of a soft material (i.e. graphite) and one made of a harder material (e.g. tungsten).

CT Pump

The seals for the CT pumps are protected from debris by cyclone separator and seal coolers. The CT Pump seal is a 4 inch John Crane Type 1B. The seal faces are separated by less than 1 micron.

From NUREG/CR-2792 (circa 1982) [Ref. 9.O], note that the size of debris of concern for increased wear at that time was chemical precipitates, 3 to 10 microns. Coating Debris generated by the LOCA start around 10 microns and go up in size [NEI 04-07]. Latent debris (dust and sand) also start at 10 microns. The size of chemical precipitates would still be the debris of concern.

From WCAP-16530-NP , note that the data reflects much larger sizes due to agglomeration of particles.

> *"...the types of precipitates generated from the reaction of dissolved containment materials tend to flocculate, resulting in agglomerated particles with sizes in the range of 10 to 100 (microns). These particles are comprised of primary particles (flocculi) of submicron size, and will likely break up under shear."*

This is consistent with NUREG/CR-2792.

Based on the debris sizes from the guidance documents for GSI-191, debris particles are too large to get between the primary seal faces and increase wear.

RHR Pump

The seals for the RHR pump are dead ended as described under the seal cooler evaluation above. The RHR Pump seal is a Durametallic type of seal and per input from Flow Serve the face-to-face gap can vary from approximately 0-15 micro-inches [<0.0254 to 0.38 microns which is consistent with John Crane seals (<1 micron)]. This gap is much tighter than the 3- 10 micron particles from chemical debris and definitely much smaller than the more realistic 10 to 100 microns sized particles described above in WCAP-16530-NP and the NEI guidance. Therefore, it is not likely that debris could enter the gap in the seals and increase wear.

SI Pump

The seals for the SI pump are dead ended. The SI Pump seal is a John Crane 2.75 in. Type 1B. Per communications with John Crane the face-to-face gap is less than 1 micron. This gap is much tighter than the 3- 10 micron particles from chemical debris and definitely much smaller than the more realistic 10 to 100 microns sized particles described above in WCAP-16530-NP and the NEI guidance. Therefore, it is not likely that debris could enter the gap in the seals and increase wear.

Centrifugal Charging Pump
The seals for the CC pump are dead ended. The CC Pump seal is a John Crane 3.250 inch Type 1B. The CCP seal is included in the input provided by John Crane for the Type 1B seal. This gap is much tighter than the 3- 10 micron particles from chemical debris and definitely much smaller than the more realistic 10 to 100 microns sized particles described above in WCAP-16530-NP and the NEI guidance. Therefore, it is not likely that debris could enter the gap in the seals and increase wear.

3.m.5 Mechanical Seal Failure

Recommendations in WCAP-16406-P, Section 10.5.2, regarding the secondary seals in the pump mechanical seals were also evaluated in EVAL-2001-002201-20-00, Evaluate mechanical seals on ECCS and CT Pumps for Leakage requirements and for the effect of failure of the seal and disaster bushing [7.G.16].

The ECCS and CT pumps each have two mechanical seals. Each mechanical seal has a primary seal and a secondary seal (or disaster bushing).

For CPNPP, the assumption of a single passive failure in the long term for the Emergency Core Cooling System is bounded by an assumed failure of a primary seal in a RHR Pump mechanical seal. It has been previously assumed that the disaster bushing would limit the leak to 50 gpm. Leak detection is provided to assure the failure is identified and isolated within 30 minutes. [Ref. 2.B] Because CPNPP has ESF Filtration for all areas that contain recirculating sump fluid, no radiological dose calculations are required for the scenario.

The assumption that the disaster bushing would limit the failure to 50 gpm is in question. The presence of debris would result in rapid failure of the disaster bushing. To estimate the maximum amount of leakage that could escape through a postulated main seal, an evaluation of each of the pump seals was conducted.

The overall pump main seal diametrical areas were calculated. This diametrical area was converted to an equivalent "hole" area and an orifice pressure drop calculation was utilized [Reference CRANE #410] to establish a leakage rate. This key geometry information was then used to estimate the leakage through a failed seal. Next, the assumption was made that the main seal failed and no credit was taken for the disaster bushings (also referred to as the back-up seals).

The smallest path opening was selected to estimate the leakage flowrate. For the CT and RHR pumps, the leakage path is between the shaft and the mating ring (barrel sleeve). For the SI and CCP pumps the disaster bushing (auxiliary gland) dimension is the limiting flow path dimension. An equivalent orifice hole size for this annulus flow area is used to calculate the flow leakage. The equivalent orifice hole size is used to determine the flow contraction resistance factor (K), which is utilized in the flow equation.

The upstream seal pressure utilized was obtained from the seal design drawings except for the Durametallic seal pressure drop - for the RHR pump seals. Since the drawing did not display a rated pressure at the seals, a conservative estimate of the suction pressure plus 10% of the discharge pressure was utilized - per the manufacturer's suggestion.

The results of the calculation shows that if the main seal in each type of pump failed due to debris erosion, the associated flowrates would be estimated as:

Containment Spray (CT): 98 gpm
Residual Heat Removal (RHR): 198 gpm
Safety Injection (SI): 59 gpm
Centrifugal Charging (CCP): 77 gpm

These flow rates are considered very conservative as no credit was taken for the upstream pressure drop from the cyclone separators as well as the seal coolers for the CT pumps. Also, since no dimensional information for the throttle bushings was readily available no credit was assumed for the bushings. This assumption was made along with the one that assumes the main seal graphite material has completely worn away and since the disaster bushing is not designed to withstand pressure or debris, it too was completely gone. This conservative analysis does not show that the 50 gpm assumption is not valid. It only intended to give a bounding number for the GSI-191 analysis.

The CT, SI, and RHR pumps are all located in individual rooms at the lowest elevation of the Safeguards buildings (El. 773). Train A and Train B are separated by a water tight wall. A safety related sump with two active Train associated sump pumps designed to detect and mitigate leakage such as from a seal failure. Each of the pumps was nominally designed for 50 gpm; however, they pump much higher rates in the as-built configuration. Failure of a pump seal is an assumed failure which requires stoppage of that pump in 30 minutes to terminate the leak. The drains in each room are designed to handle a minimum of 50 gpm. If the leak exceeds the drain rate, water could back up in the room; however, only the failed pump could be affected. If the drain rate exceeds the leak, the sump pumps would likely keep up with the in-flow. If water did back up in the sump room or the other pump rooms, only the failed train would be affected. Because CPNPP has ESF filtration, radiological consequence analysis for the postulated seal failure is not required (assumed trivial). The increase leak rate is not significant enough to change this. Because the water is pumped to the floor drain tank, there is minimal impact on humidity and no impact on equipment qualification.

The CCPs are located in the Auxiliary Building at Elevation 810 (plant grade). Unit 1 CCPs located in Rooms 200 and 201 drain directly to Floor Drain Tank #1. Unit 2 CCPs located in Rooms 194 and 194 drain to Floor Drain Sump #12. The sump pumps in Sump #12 are not safety related. If they did not work, water could back up into various rooms; however, the water would be spread out over a large floor area 77 gpm is only a minor increase over the previous 50 gpm assumption. This is considered a trivial increase which would not appreciably change flooding or humidity.

A leakage of 200 gpm from the recirculation water is acceptable for a short period (i.e. 30 minutes) because the 6,000 gallon water lost due to the leak is an insignificant percentage of the total sump water volume.

The question of the auxiliary seal design and alternative materials was discussed with the seal vendor who advised the auxiliary bushing could be fabricated from a bronze material; however, the vendor has not designed a bronze secondary bushing for seals used in the pumps.

Therefore, based on the evaluation of worst case leakage and the lack of a vendor design, the recommendation to replace the secondary seal material was not pursued.

Section 3.n Downstream Effects - Fuel and Vessel

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

Testing and analysis of downstream effects were completed in accordance with WCAP-16406-P-A, Evaluation of Downstream Sump Debris Effects in Support of GSI-191[Ref. 6.A] and the NRC Safety Evaluation [Ref. 1.E].

3.n.1 Reactor Vessel Blockage

Analysis for reactor vessel blockage is documented in CN-CSA-05-19, Comanche Peak Steam Electric Station Units 1 and 2 GSI-191 Downstream Effects – Vessel Blockage Evaluation [7.E.3]

This evaluation assumed a maximum particle size of 0.127 in. x 0.230 in. These are the maximum dimensions of deformable particulate debris passing through a sump screen with 0.115-inch diameter holes (original CPNPP design). This is a conservative assumption based on WCAP-16406-P (Ref. 6.A). It assumes that the thickness and/or width of deformable particulate debris that may pass through the sump screen is limited to the size of the flow passage hole in the sump screen, plus 10% (i.e., 1.10 * 0.115 in = 0.127 in) and that the maximum length of deformable particulate debris that may pass through the flow passage hole in the sump screen is twice the diameter of the flow passage hole (i.e., 2 * 0.115 in = 0.230 in). The maximum dimension of non-deformable particulate debris is limited to the size of the flow passage hole in the sump screen (Ref. 6.A) and is thus smaller than the deformable debris. Although the maximum length of fibrous insulation debris from Ref. 6.A is larger (the thickness of fibrous insulation as installed inside containment or four inches, whichever is larger), this is not limiting with respect to blockage of the essential flow paths through the reactor internals since the fibrous debris is flexible.

In order to determine if the flow paths through the reactor vessel internals can accommodate debris that has passed through the sump screens without significantly disrupting flow to the core, a number of locations within the reactor vessel were identified as points of interest (POIs) for possible flow restriction. Once identified, the POIs were evaluated using verified drawings to determine limiting dimensions and flow areas.

It was found that dimensions of the essential flow paths through the reactor internals are adequate to prèclude plugging by sump debris. There is sufficient clearance for debris that may pass the containment sump screen, as the limiting dimensions of the essential flow paths in the upper and lower internals are all greater than the maximum particle dimension of 0.230 inches. The maximum particle dimension is twice the sump screen hole diameter. The sump screen hole diameter evaluated was 0.115 inches, which is larger than the current sump screen size of 0.095 inches (See Section 3.j).

The smallest clearance found is 2.10 inches, which means that any sump screen size smaller than 1.05 inches will prevent plugging by sump debris in CPNPP Units 1 and 2.

3.n.2 In Vessel Effects - Blockage

CN-CSA-05-70, Comanche Peak Units 1 and 2 GSI-191 Downstream Effects – Reactor Fuel Blockage Evaluation [7.E.4]

The method used for this evaluation was based on a simplified version found in WCAP-16406-P, Revision 1 (Section 9 and Appendix N of Ref. 6.A). First, the underside of the fuel assembly bottom nozzle is treated as a flat plate. Then, the fibrous debris that passes through the sump screen will collect on the underside of the fuel assembly bottom nozzle, and build up at a density equal to its as-manufactured density.

The total volume of fiber bypass will be determined by multiplying the volume of fibrous debris by the plant-specific screen bypass fraction (if the plant-specific bypass amount is provided, then that value will be used directly). Lastly, the volume of bypassed fiber will be divided by the total area of the fuel assembly bottom nozzles to determine the fiber bed thickness.

Input was from provided by Ref. 7.A.5 and Ref. 7.E.5:

- Antisweat Fiberglass – 13.598 ft3
- Lead Blanket Fiberglass – 0.340 ft3
- Min-K – Fiber – 0.693 ft3
- Lead Wool Debris – 0.215 ft3
- Latent Fibrous – 10.000 ft3
- Fiber Bypass Fraction – 5%
- Core Area – 96.062 ft2 (Ref. 6)

There is no formal acceptance criterion for this evaluation. This evaluation is performed to determine if a fiber bed greater than 0.125 inches will form on the underside of the fuel assemblies bottom nozzle following a LOCA. The 0.125 inch thick fiber bed criterion was established to indicate the threshold where thin bed head loss effects may occur (Ref 6.A, Appendix N).

The amount of fiber that is predicted to bypass the sump screens produces a theoretical fibrous debris bed of 0.155 inches which is greater than the 0.125 inch screening criterion. This indicates that the fiber bed formed on the underside of the fuel assembly bottom nozzle may be capable of inducing thin bed effects leading to possible head loss at the core entrance.

To demonstrate reasonable long-term core cooling, a PWROG program captured in WCAP-16793-NP (Ref. 6.F) demonstrated that the effects of fibrous debris, particulate debris, and chemical precipitation would not prevent adequate long-term core cooling flow from being established for all plants. The specific conclusions reached by WCAP-16793 include:

- Adequate flow to remove decay heat will continue to reach the core even with debris from the sump reaching the RCS and core. Test data has demonstrated that debris that bypasses the screen and collects at the core inlet will provide some resistance to flow but this is not likely to build up an impenetrable blockage at the core inlet. In the case where large blockage does occur, numerical analyses have demonstrated that core decay heat removal will continue. Per WCAP-16793, this conclusion is applicable for all plants and thus applies to Comanche Peak Units 1 and 2.

- Decay heat will continue to be removed even with debris collection at the fuel assembly spacer grids. Test data has demonstrated that any debris that bypasses the screen is small and consequently is not likely to collect at the grid locations. Further, any blockage that may form will be limited in length and not be impenetrable to flow. In the extreme case that a large blockage does occur, numerical and first principle analyses have demonstrated that core decay heat removal will continue. Per WCAP-16793, this conclusion is applicable for all plants and thus applies to Comanche Peak Units 1 and 2.

- Should fibrous debris enter the core region, it will not tightly adhere to the surface of fuel cladding. Thus, fibrous debris will not form a "blanket" on clad surfaces to restrict heat transfer and cause an increase in clad temperature. Therefore, adherence of fibrous debris to the cladding is not plausible and will not adversely affect core cooling. Per WCAP-16793, this conclusion is applicable for all plants and thus applies to Comanche Peak Units 1 and 2.

Using an extension of the chemical effects method developed in WCAP-16530-NP to predict chemical deposition of fuel cladding, the plant-specific calculation, using the recommended methodology to confirm that plate-out on the fuel does not result in the prediction of quenched fuel cladding reheating to temperatures approaching the 800 F acceptance criterion, was performed by Comanche Peak Engineering and is described in 3.n.3 below.

Given the statements provide above, it is concluded that there is reasonable assurance of acceptable long-term core cooling for Comanche Peak Units 1 and 2 considering debris and chemical products in the recirculating fluid and fibrous debris build up on the bottom of the core.

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3.n.3 In Vessel Effects - Long Term Core Cooling

The Pressurized Water Reactor Owners Group (PWROG) undertook a program to provide additional analyses and information on the effect of debris and chemical products on core cooling for pressurized water reactors (PWRs) when the emergency core cooling system (ECCS) is realigned to recirculate coolant from the containment sump. The objective of the program was to demonstrate reasonable assurance that sufficient long-term core cooling (LTCC) is achieved for PWRs to satisfy the requirements of 10 CFR 50.46 with debris and chemical products that might be transported to the reactor vessel and core by the coolant recirculating from the containment sump. The debris composition includes particulate and fiber debris, as well as post-accident chemical products. The program was performed such that the results of this program apply to the fleet of PWRs, regardless of the design. A description of the program and summary of the results is given in technical report WCAP-16793-NP, Revision 1 [Ref. 6.F] and is intended to be used by licensees to demonstrate reasonable assurance of LTCC for all PWRs.

Upon NRC approval of WCAP-16793-NP, Rev. 1, the evaluation of Comanche Peak Nuclear Power Plant and fuel will be finalized. The evaluation is to be performed using both test data and a predictive spreadsheet calculation tool that are part of Rev. 1 of WCAP-16793-NP, and account for conditions and limitations identified by NRC in their safety evaluation report (SER) issued on WCAP-16793-NP.

3.n.3.1 Plant-specific Debris Load

A comparison [Ref. 7.E.8] was made to demonstrate that the CPNPP-specific debris load that reaches the RCS is less than the generic acceptance criteria identified in Rev. 1 of WCAP-16793-NP.

Debris	WCAP-16793-NP, R1	CPNPP
Fiber	0.33 lb	0.02 lb
Particulate	29 lb	98.78 lb
Chemical	13 lb	1.26 lb
Calcium silicate	6 lb	N/A
Microporous Insulation	3.2 lb	0.03 lb

The table above shows Comanche Peak is within the limits established for fiber, chemicals and microporous materials but outside of the particulate limit.

Even though the Comanche Peak particulate load is greater than the published particulate acceptance criterion, Comanche Peak demonstrates reasonable assurance of LTCC. Instead of evaluating the individual debris types of the acceptance criteria, the combination of debris types must be evaluated in order to determine reasonable assurance of LTCC. As illustrated in WCAP-17057-P [Ref. 6.K], when the debris load consists of fiber, particulate, chemical and microporous, the quantity of fiber has the greatest effect on the dP. The effects of chemical, particulate and microporous are considered negligible.

The executive summary and Section 6 of WCAP-17057-P has further discussions about the effects of chemical, microporous and particulate. Additionally, the effect of particulates, chemicals and microporous is illustrated in the time-history data plots presented in Appendix B of WCAP-17057-P.

As stated in WCAP-17057-P, fiber has the greatest effect on the total dP. From the time-history data plots presented in Appendix B of WCAP-17057-P, a fiber load of approximately 0.022 lb/fuel assembly does not result in a significant dP regardless of the quantity of other debris. Operating at the stated fiber load provides Comanche Peak with significant margin for allowable fiber per fuel assembly. Based on the discussions provided in WCAP-17057-P and the time-history plots of Appendix B, Comanche Peak is assured of LTCC at quantities as high as ten times the current reported fiber bypass load.

3.n.3.2 LOCADM Calculation

To demonstrate reasonable long-term core cooling, a long term core cooling analysis was performed in accordance with WCAP-16793-NP (Ref. 6.F) and PWROG Letter OG-07-534, "Transmittal of Additional Guidance for Modeling Post-LOCA Core Deposition with LOCADM Document for WCAP-16793-P," December, 14,2007

This analysis is documented in RXE-LA-CPX/0-101, Post LOCA Long Term Cooling Calculation for CPNPP Considering Particulates and Chemical Debris [7.F.23]

Item 13 of NRC Letter dated February 4, 2008 to Anthony Pietrangelo, NEI, Draft Conditions and Limitations for Use of Westinghouse Topical Report WCAP-16793-NP, Revision 0, "Evaluation of Long-term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid" [Ref. 1.F] was considered in the analysis as suggested by Ref. 6J.

[NOTE: Analysis of the in-vessel downstream effects were in accordance with WCAP-16793-NP, Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid [Ref. 6.F]..The NRC staff has not issued a final SE on this WCAP. The completed analysis may require a revision depending on the final resolution of the issues.]

The calculation of the post LOCA long term fuel temperatures takes into consideration particulate and chemical debris in the recirculating fluid. The calculation explicitly considers the degradation of heat transfer associated with: (a) chemical deposition on the cladding resulting from impurities in the recirculating fluid, (b) initial oxide and crud layers, as well as (c) the oxidation resulting from the zirconium-water reaction that takes place during the LOCA. The calculations utilize the methodology described in WCAP-16793 and CPNPP- specific input.

The maximum fuel cladding temperature at the Maximum thickness occurred at the time of recirculation, i.e. cladding temperatures go down continuously with time. This means that while some varying sensitivities affected the LOCA scale thickness, the accumulation of LOCA scale on the fuel did not reduce heat transfer enough to offset the effect of cooler water recirculating via RHR heat exchangers and the reduction in decay heat even as scale builds up.

Section 3.o Chemical Effects

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

Testing and analysis of chemical effects were completed in accordance with WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191", Revision 0, February 2006. [REF. 6.B] and NRC Safety Evaluation [REF. 1.G].

3.o.1 Comparison to Integrated Chemical Effects Tests (ICET)

A comparison of CPNPP materials to Integrated Chemical Effects Tests (ICET) [Ref. 10.A and Ref. 10.B] was performed in EVAL-2001-002201-04 [Ref. 7.F.1]

Material	**Estimated Quantity (CPNPP)**	**Ratio of CPNPP to ICET spray zone**	**Ratio of CPNPP to ICET submerged zone**
Zinc in Galvanized Steel	191,000 (ft2)	191,000 x .95/ 588,344 = 0.31	191,000 x 0.05/29,417 = 0.32
Inorganic Zinc Primer Coatings (non-top coated)	196,340 (ft2)	196,340 x .96/338,298 = 0.56	196,340 x .04/13,532 = 0.58
Aluminum	744 (ft2)	744 x .89/257,401 = 0.003	744 x .11/12870 = 0.006
Copper (including Cu-Ni alloys)	14,000 (ft2)	14,000 x 1 / 441,258 = 0.03	N/A
Carbon Steel	1,400 (ft2)	1,400 x .95 / 11,031 = 0.12	1400 x .05 / 3751 = 0.02
Concrete (surface)	9800 (ft2)	9800 x .9 / 3309 = 2.7	9800 x .1 / 1125 = 0.9
Concrete (particulate)	103 (lbm) assumed	N/A	1.0

NOTE: The estimated quantities above were only for the purposes of comparison and are not maintained current.

Aluminum scaffold materials were removed from containment at the end of 1RF12 and 2RF09.

From Ref. 7.F.33, ME-CA-0232-5018, Analysis of pH for containment spray and containment sump solution:

> The minimum sump pH is greater than 8.25 which corresponds to the beginning of the fuel cycle.
>
> The maximum sump pH is less than 9.2 which corresponds to the end of the fuel cycle.

The ICET Test 1 environment was the most similar to CPNPP. Boric Acid bounded CPNPP (i.e., 2800 ppm versus 2600 ppm). NaOH was added as required to reach a pH of 10 which bounds the CPNPP maximum sump pH.

The design of the RWST assures that the initiation of ECCS recirculation does not occur in less than 10 minutes after a LBLOCA. [Ref. 7.F.18]. The peak sump temperature at the time of ECCS recirculation is 265 °F maximum [Ref. 8.A.1]. The pool volume would still be increasing for a period less than 25 minutes due to sprays until the minimum pool volume reaches 59,819.5 ft^3 [Ref. 7.F.17]. This volume would then increase with time as the hold up in the atmosphere decreases with temperature.

Pool temperatures and volumes after initiation of recirculation are not typically calculated; however, Ref. 7.F.23 estimated the containment sump temperature at 24 hours to be 165 °F.

3.o.2 Calculation of Chemical Precipitates

Inventory calculations and logs which had been developed for the purposes of combustible gas control were evaluated for GSI-191 purposes. Starting with the combustible gas control inventories, a series of walk downs using a portable alloy analyzer were performed to confirm logged aluminum as well as identify unlogged aluminum. [Ref. 3.I] The aluminum inventory in containment has been calculated in ME-CA-0232-5395, Unit 1 and Unit 2 Aluminum Inside Containment. [Ref. 7.F.35]

A number of items were identified and added to the inventory.

The aluminum inventory now includes an allowance of 882 ft^2 of coatings which may contain aluminum for valves less than 4 inches. [Ref. 7.F.35]

Protective coatings containing aluminum were allowed on cold water piping which is covered by anti-sweat insulation and clad in stainless steel. Only the portion exposed by destruction of the insulations would be exposed to spray. Cold water pipes which are in the ZOI for LOCA have a maximum surface area of 52.9 square feet. [Ref. 7.F.35]

CPNPP specifications require stainless steel RMI and stainless steel jacketing on anti-sweat insulation. No aluminum is associated with insulation.

As part of the effort to inventory aluminum, removal of aluminum was considered and implemented when practical. For example, aluminum scaffold planks previously stored in containment at power were removed [Ref. 3.I]. As part of aluminum reduction modifications, an aluminum ladder stored in containment at power is now stored in a stainless steel box, aluminum handrail fittings were replaced with galvanized iron fittings or wrapped with Raychem tape to isolated them from spray, and aluminum signs used for radiation protection postings were replaced [Ref. 3.J].

After aluminum reduction design changes were implemented, the Unit 1 results were a total of 385.4 ft^2 aluminum and 502.0 lbm. The portion of Aluminum below elevation 817' (submerged) in Unit 1 equals 141.6 ft^2 and 355.8 lbm.

Unit 1	Surface Area (ft^2)	Total Mass (lbm)
Submerged (Below el 817')	141.8	356.1
Non-Submerged (Above el 817')	243.7	145.9
Total	385.5	502.0

After aluminum reduction design changes were implemented, the Unit 2 results were a total of 352.0 ft^2 aluminum and 484.5 lbm. The portion of Aluminum below elevation 817' (submerged) in Unit 2 equals 147.8 ft^2 and 356.4 lbm.

Unit 2	Surface Area (ft^2)	Total Mass (lbm)
Submerged (Below el 817')	147.8	356.4
Non-Submerged (Above el 817')	204.3	128.1
Total	352.1	484.5

These reductions created design margins in the amount of aluminum included in sump qualification testing described below.

ME-CA-0000-5415, Containment Sump Chemical Model & Effects Using Current & Alternate Buffering Agents [Ref. 7.F.32] was completed in accordance with WCAP-16530-NP.

Total Calcium Phosphate ($Ca_3(PO_4)_2$)	**Total Sodium Aluminum Silicate ($NaAlSi_3O_8$)**	**Total Aluminum Oxyhydroxide (AlOOH)**	**Total Precipitate**
0.0 kg	78.6 kg	16.4 kg	94.9 kg
0.0 lbs	173.2 lbs	36.1 lbs	209.3 lbs
0.0 ppm	41.7 ppm	8.7 ppm	50.4 ppm

No credit was taken for solubility.

Note that the current estimate of 209.3 lbs total precipitate is 34.4 lbs less than was specified for strainer qualification testing described below.

Specified for Strainer Testing [Ref. 8.A.1]		
Chemical Byproducts (lbm)		Total 243.7 (59 ppm)
	$NaAlSi_3O_8$ Precipitate	173.2 (42 ppm)
	AlOOH Precipitate	70.5 (17 ppm)

RAI 36 Additional design margin would be created by a change or a reduction in the buffer concentration. Change to TSP versus a reduction of NaOH was evaluated and the NaOH reduction was selected as the best option. A license amendment was submitted and approved that would allow CPNPP to reduce the buffer concentration (to reduce the pH impact) under 10CFR50.59 [Ref. 9.B] in the future [Ref. 2.J and Ref. 2.C.2]. The total precipitate change projected for a reduction of NaOH concentration is almost 90 lbs (from 209.3 lbs to 119.6 lbs). However, since the strainer was qualified for the specified quantity which already has a 34.4 lb margin, this potential modification was not required to complete GL 2004-02 actions. Although there are no current plans to implement the modification, the benefits may warrant it in the future. No time table has been established for implementation of buffer concentration reduction.

NOTE: The results of WCAP-16596-NP [Ref. 6.D] show that sodium metaborate, in solution form, would be a suitable replacement for sodium hydroxide solution. However, this change would require another License Amendment to change Technical Specification 3.6.7.

3.o.3 Qualification of Emergency Sump Strainer with Chemical Effects

3.o.3.1 LOCA

Based on observations of early testing with chemical precipitates with vertical loops, CPNPP elected to conduct prototypical testing of a full size module as described in Section 3.f. Bench top testing was not considered.

The strainer qualification testing was performed with heated city domestic (tap) water. The test temperature was less than 120 °F which is a conservatively low temperature for testing.

Chemical effects were included in the test results which were extrapolated to 30 days. See section 3.f.4.2 for the head loss calculation results. The minimum NPSHa margin is 5 ft at 212 °F as calculated in accordance with RG 1.1 and RG 1.82 [Section 3.g.1].

RAI 35 Because chemical precipitates were first observed at and below 140 °F, the total strainer head loss was calculated at 120 °F for information and comparison only and is slightly higher (i.e., 0.3 feet) than at 212 °F. This slight increase would be offset by increases in sump water level from condensed steam. When compared to the contribution of the air partial pressure (Section 3.g.2), the increase in head loss at the lower temperature is insignificant.

CONSERVATISM - No credit for solubility or the increased NPSH margin was taken.

3.o.3.2 Secondary Line breaks

A comparison of the predicted debris load for MSLB to the prototype testing for the strainer was made in Section 3.e.4. Based on lower approach velocities for MSLB, the shorter sump mission time (1 day versus 30), and the previous test results, it was determined that LOCA testing with chemicals would bound the MSLB effects.

Section 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.

RAI 37 NOTE: Although secondary line breaks were evaluated for arbitrary break locations, the licensing basis for secondary line break locations and their effect on emergency sump performance was not changed. The bounding design basis break for emergency sump performance is LOCA. [Ref. 2.R]

3.p.1 Changes to the Technical Specifications

License Amendment 129 approved LDCR-TS-2005-003 [Ref. 2.C.1 and 3.G]

- Revise TS 3.3.2 RWST Setpoint Allowable Value,
- Revise description of sump screens to strainers in SR 3.5.2.8

These changes were required to support the design and installation of the new emergency sump strainers.

License Amendment 129 approved LDCR-TS-2007-005 [Ref. 2.C.2 and 3.J]

- Revise TS 3.6.7, "Spray Additive System"

This change was made to enable future changes to the spray additive system under 10CFR50.59 which would increase margins and benefit safety in the areas of equipment qualification and emergency sump performance.

3.p.2 Changes to the Licensing Basis in the FSAR for Modifications

Changes to the licensing basis for the completed plant modifications have been made.

The FSAR updates were performed in accordance with the requirements of 10CFR50.71(e).

Completed changes to the licensing basis in Comanche Peak Steam Electric Station Final Safety Analysis Report (FSAR), Amendment 101, February 1, 2007. [REF. 2.B]]

- LDCR-SA-2005-024, Update for the change to the radiation protection doors and barriers modified by MCA-2002-001952-03. Correct FSAR Appendix 1A(B) and Section

6.2.2.3.3 for descriptions of the emergency sump and RG 1.82. [REF. 2.B.1]

- LDCR-SA-2006-001, Update for removal of the personnel barriers beneath the fuel transfer tube inside containment by FDA-2005-003364-07 and -17. [REF. 2.B.2]

- LDCR-SA-2006-010, Update for LA129 and GSI-191 mods:
  - FDA-2005-003364-02 and 12 - Replace RWST/CT Isolation Valves HV-4758/4759
  - FDA-2005-003364-03 and 13 - Replace Sump Screens/Trash Racks with Sump Strainers/Debris Interceptors
  - FDA-2005-003364-04 and 14 - Add Drain Strainers and Debris Screens in Refueling Cavity Drains
  - FDA-2005-003364-05 and 15 - Reduce spray water holdup
  - FDA-2005-003364-09 and 19 - RWST Setpoint Mod
  - Tech Spec LA 129 to TS Table 3.3.2-1 (RWST Low-Low Allowable value) and SR 3.5.2.8 (sump surveillance).

  [REF. 2.B.3]

- LDCR-SA-2007-019, clarify the type of insulation used inside containment [REF. 2.B.5]

- LDCR-SA-2007-022, Update the Protective Coatings Program description in the FSAR [2.B.6]

- LDCR-SA-2005-029, Addition of narrow range suction pressure instrumentation for RHR and CSS pumps, RG 1.97 R2 Type 2D accident monitoring by FDA-2005-003364-08 and -18 [REF. 2.B.4]

3.p.3 Change to the Licencing Basis for Emergency Sump Performance

Change to the licensing basis in Comanche Peak Steam Electric Station Final Safety Analysis Report (FSAR), Amendment 102, August 1, 2008. [REF. 2.B]

- LDCR-SA-2006-36, Update for the changes to the emergency sump licensing basis [REF. 2.B.7]

The CPNPP licensing basis was updated on August 31, 2008, to reflect the results of the analysis and modifications performed to demonstrate compliance with the regulatory requirements. The FSAR incorporation was performed in accordance with the requirements of 10CFR50.71(e).

In general, the FSAR was revised as follows:

- Table 6.1B-1 to update for organic materials, including cables and oil
- Section 6.2.2.3.3 and 6.2.2.3.4 are revised to reflect the GSI-191 analysis and testing.
- Table 6.2.2-4 is administratively updated per 10CFR50.71(e) to update and clarify the material description for the sump strainers.
- Section 6.3.2.2.10 is updated for changes to the sump design and licensing basis to reflect the results of the mechanistic analysis requested in Generic Letter 2004-02. Section 6.3.2.2.10 is revised to reflect the NPSH analysis for RHR.

The significant additions were as follows:

INSERT to Section 6.2.2.3.3

In response to Generic Letter 2004-02 [Ref. 6], the emergency sump design was modified to replace the flat screen based design with a complex strainer based design with an effective factor of 20 increase in surface area . An analysis of the susceptibility of the ECCS and CSS recirculation functions for Units 1 and 2 was performed. This analysis provides plant specific evaluations of upstream effects, debris generation, and debris transport to the ECCS and CSS recirculation sump. The head loss associated with debris accumulation, and its associated effect on available net positive suction head were demonstrated by testing. The structural capability of the sump strainers under debris loadings was also evaluated. The downstream effects of debris that passes through the screens on components in the recirculation flow path such as pumps, valves, orifices, spray nozzles, and core components were also evaluated. The testing and analyses provide the basis to show compliance with the applicable regulatory requirements including 10CFR50.46; 10 CFR 50 Appendix A, General Design Criteria 35, 38 and 41; and10CFR100.

The NRC has approved the methodology for meeting Generic Letter 2004-02 using the guidance of Nuclear Energy Institute (NEI) document titled "*Pressurized-Water Reactor (PWR) Sump Performance Methodology,*" dated May 28, 2004 as approved and supplemented by the NRC in a SER dated December 6, 2004. The sump performance methodology and the associated NRC SER have been issued collectively as NEI Report NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, dated December 2004. [REF. 7]

The methodology used employs plant specific refinements, as allowed by the NRC SER. Additional data and methodology from ongoing research on specific issues such as downstream effects, chemical effects, and coatings were also used to the extent possible. The methodology was supplemented with plant specific design and licensing basis information and contractor specific proprietary information and data as appropriate with the current state of knowledge. Exceptions and/or interpretations being taken to the guidance given in NEI 04-07 as modified by the SER are described in the responses to the Generic Letter.

INSERT to 6.2.2.3.3

Analysis and testing of potential debris sources has shown that the primary debris of concern for sump performance is the combination of fibrous debris, particulate, and chemical precipitate. Fibers from fiberglass antisweat insulation located on cooling and chilled water lines and from latent debris are capable of transporting to the strainer surface. The covers for lead shielding blankets also contain fiberglass which could be within the zone of influence of a LOCA. High efficiency themal insulation (Min-K) is made of both fibrous and particulate materials. Particulate of concern includes latent debris and coating debris. The chemical precipitates of concern result from the interaction of containment spray with aluminum. Debris generation analyses have conservatively determined bounding quantities of these and other materials that could be generated by a loss of coolant accident or a secondary line break.

INSERT to 6.2.2.3.3

Debris transport analysis has conservatively determined bounding quantities of the materials identified in the debris generation analyses that could be transported to the vicinity of the recirculation sumps. In addition to particulate and fiber, latent debris was assumed to include labels, tape, and other miscellaneous materials which could be present in containment. The results of the debris generation and debris transport analyses are combined to determine the design basis debris load for strainer qualification testing. See Section 6.2.2.3.4.

INSERT to 6.2.2.3.3

Testing has shown that reflective metal insulation debris will not transport to the strainers and that this debris is beneficial in that it would capture, and/or impede the transport of, fibrous debris.. However, no credit for the beneficial aspects of RMI was taken in the analyses or testing.

INSERT F to 6.2.2.3.4

The NPSH margin is calculated based on a clean strainer and minimum containment water levels during containment spray recirculation. The design basis debris head loss is determined by prototypical testing of a full size strainer with the design basis debris load as described in Section 6.2.2.3.3 scaled to the test configuration. This testing has shown that significant NPSH margin remains after the design basis debris head loss is subtracted from the clean strainer NPSH margin.

INSERT to Section 6.2.2 References

6. NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-water Reactors"

7. NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, dated December 2004.

8. TXX-05162 dated September 1, 2005, Response to Requested Information Part 2 of NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-water Reactors"

9. TXX-08033 dated February 29, 2008, Supplement to Response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-water Reactors"

Section 4.0 References

References used in this report (e.g. "REF. #. ") are grouped and listed below . Additional references are provided in Section 3.k.

4.1 NRC Correspondence

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

1.B NRC Letter dated December 27, 2007, "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" (TAC NOS. MD4676 AND MD4677) [CP-200800066]

1.C NRC Letter dated February 9, 2006, Request for Additional Information Regarding Response to Generic Letter 04-002 Potential Impact of Debris Blockage on Emergency Recirculation During Design-basis Accidents at Pressurized-water Reactors" (TAC NOS. MC4776 AND MC4777)

1.D NRC Letter dated November 30, 2007 to Anthony Pietrangelo, NEI, Supplemental Licensee Responses to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-water Reactors"

1.E Safety Evaluation by the Office of Nuclear Reactor Regulation Topical Report (TR) WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191" Pressurized Water Reactor Owners Group Project No. 694, December 20, 2007.

1.F NRC Letter dated February 4, 2008 to Anthony Pietrangelo, NEI, Draft Conditions and Limitations for Use of Westinghouse Topical Report WCAP-16793-NP, Revision 0, "Evaluation of Long-term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid"

1.G Final Safety Evaluation by the Office of Nuclear Reactor Regulation Topical Report WCAP-16530-NP "Evaluation of Post-accident Chemical Effects in Containment Sump Fluids to Support GSI-191" Pressurized Water Reactor Owners Group Project No. 694, December 21, 2007.

1.H NRC Letter from William H. Ruland to Anthony Pietrangelo, NEI, Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, dated November 21, 2007.

1.I NRC Letter from William H. Ruland to Anthony Pietrangelo, NEI, Revised Guidance for Review of Final Licensee Responses to GENERIC LETTER 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors", dated March 28, 2008. [ADAMS Accession # ML080230234]

1.J NRC Letter from Balwant K. Singal to M. R. Blevins, Luminant, GENERIC LETTER 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," Extension Request, dated June 27, 2008.

1.K NRC Letter from Balwant K. Singal to Rafael Flores, Luminant, Request for Additional Information Regarding Response to Generic Letter 2004-02, " Potential Impact of Debris Blockage on Emergency Recirculation During Design-basis Accidents at Pressurized-water Reactors", dated July 15, 2009 [ADAMS Accession # ML091670738]

1.L Summary of July 9, 2009, Category 1 Meeting with Luminant Generation Company LLC on Resolution of Generic Letter 2004-02 dated July 31, 2009 [ADAMS Accession # ML091970578]

The following meeting slides are located in the Agencywide Documents Access and Management System (ADAMS):

- Meeting Agenda (ADAMS Accession No. ML091940275)
- NRC Introductory Remarks (ADAMS Accession No. ML091940276)
- Luminant Holistic Analysis (ADAMS Accession No. ML091940277)
- Alion, discussion on RAI 9 and 6 (ADAMS Accession No. ML091960449)
- Alden discussion on RAI 10 and 11 (ADAMS Accession No.

ML091940278)
- AREVA and PCI discussion on RAI 15, 8 and 20 (ADAMS Accession No. ML091940083)
- Luminant discussion on RAI 22 and 23 (ADAMS Accession No. ML091940084)
- Luminant discussion on RAI 24 and 37 (ADAMS Accession No. ML091940085)

1.M Staff Observations Regarding Flume Testing of a Prototype Portion of the Proposed Replacement Suction Screen Design for the Comanche Peak Steam Electric Station (DOCKET NOS. 50-445 AND 50-446) dated June 30, 2006 [ADAMS Accession # ML061710147]

1.N Summary of August 10, 2009, Category 1 Meeting with Luminant Generation Company LLC on Resolution of Generic Letter 2004-02 dated September 1, 2009 [ADAMS Accession # ML092330062]

1.O ADAMS Accession Nos. Package ML082050446 (Letter ML082050406, Audit Report ML082050433), "Indian Point Nuclear Generating Unit Nos. 2 and 3 – Report on Results of Staff Audit of Corrective Actions to Address Generic Letter 2004-02 (TAC Nos. MC4689 and MC4690)", July 29, 2008.

4.2 Comanche Peak Correspondence and Other Docketed Documents

2.A Letter Logged TXX-05162 dated September 1, 2005, Response to Requested Information Part 2 of NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-water Reactors".[CPSES-200501776]

2.B Comanche Peak Steam Electric Station Final Safety Analysis Report (FSAR), Amendment 102, August 1, 2008 (except as noted).

2.B.1 LDCR-SA-2005-024, Update for the change to the radiation protection doors and barriers modified by MCA-2002-001952-03. Correct FSAR Appendix 1A(B) and Section 6.2.2.3.3 for descriptions of the emergency sump and RG 1.82. [EVAL-2002-001952-03]

2.B.2 LDCR-SA-2006-001, Update for removal of the personnel barriers beneath the fuel transfer tube inside containment by FDA-2005-003364-07 and -17. [EVAL-2005-003364-01]

2.B.3 LDCR-SA-2006-010, Update for LA129 and GSI-191 mods:

- FDA-2005-003364-02 and 12 - Replace RWST/CT Isolation Valves HV-4758/4759
- FDA-2005-003364-03 and 13 - Replace Sump Screens/Trash Racks with Sump Strainers/Debris Interceptors
- FDA-2005-003364-04 and 14 - Add Drain Strainers and Debris Screens in Refueling Cavity Drains
- FDA-2005-003364-05 and 15 - Reduce spray water holdup
- FDA-2005-003364-09 and 19 - RWST Setpoint Mod
- Tech Spec LA 129 to TS Table 3.3.2-1 (RWST Low-Low Allowable value) and SR 3.5.2.8 (sump surveillance).

[EVAL-2005-003364-03]

2.B.4 LDCR-SA-2005-029, Addition of narrow range suction pressure instrumentation for RHR and CSS pumps, RG 1.97 R2 Type 2D accident monitoring by FDA-2005-003364-08 and -18 [EVAL-2005-003364-07]

2.B.5 LDCR-SA-2007-019, clarify the type of insulation used inside containment [EVAL-2001-002201-21]

2.B.6 LDCR-SA-2007-022, Update the Protective Coatings Program description in the FSAR [EVAL-004-002882-07]

2.B.7 LDCR-SA-2006-36, Update for the changes to the emergency sump licensing basis [EVAL-2005-003364-19] [To be included in FSAR Amendment 103]

2.C Comanche Peak Steam Electric Station Technical Specifications, Amendment 147, November 13, 2008.

2.C.1 License Amendment 129: REVISIONS TO TECHNICAL SPECIFICATIONS 3.3.2, "ESFAS [ENGINEERED SAFETY FEATURES ACTUATION SYSTEM] INSTRUMENTATION"; AND 3.5.2, "ECCS [EMERGENCY CORE COOLING SYSTEM] -

OPERATING].

2.C.2 License Amendment 147: REVISIONS TO TECHNICAL SPECIFICATION 3.6.7, "SPRAY ADDITIVE SYSTEM".

2.D Letter Logged TXX-05047 dated March 7, 2005, 90-day Response to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-water Reactors. [CPSES-200500464]

2.E Letter Logged TXX-06062 dated March 31, 2006, Updated Response to Requested Information Part 2 of NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accid Ents at Pressurized-water Reactors". [CPSES-200600627]

2.F Letter Logged TXX-06180 dated October 20, 2006, Transmittal of Report on Txu Power Sponsored Coatings Performance Test. [CPSES-200602162]

2.G Letter Logged TXX-07156 dated November 8, 2007, Supplemental Information to Report on Luminant Power Sponsored Coatings Performance Test. [CP-200700051]

2.H Letter Logged TXX-03130 dated August 8, 2003, Response to NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-water-reactors". [CPSES-200301604]

2.I Letter Logged TXX-05118 dated June 27, 2005, Request for Additional Information Regarding Response to NRC Bulletin 2003-01. [CPSES-200501323]

2.J Letter Logged TXX-07149 dated November 29, 2007, License Amendment Request (LAR) 2007-008, Revision to Technical Specification 3.6.7, "SPRAY ADDITIVE SYSTEM". [CPSES-200700022]

2.K Letter Logged TXX-98249 dated November 11, 1998, Response to Generic Letter 98-0 4, "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"

2.L NUREG-0797, Safety Evaluation Report Related to the Operation of Comanche Peak Steam Electric Station, Units 1 and 2.
- Supplement 9, March 1985
- Supplement 11, May 1985
- Supplement 21, April 1989

2.M Gibbs & Hill Report, "Evaluation of Paint and Insulation Debris Effects on Containment Emergency Sump Performance," June 1984

2.N Letter Logged TXX-07164 dated December 3, 2007, Supplement to Response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors". [CPSES-200700090]

2.O Letter Logged TXX-08033 dated February 29, 2008, Supplemental Response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors". [CPSES-200800265]

2.P Letter Logged TXX-08090 dated June 18, 2008, Supplement to Response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors". [CPSES-200800834]

2.Q Letter Logged TXX-06196 dated December 13, 2006, Updated Response to Requested Information Part 2 of NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-water Reactors"[CPSES-200602416]

2.R Letter Logged TXX-09114 dated September 10, 2009, Supplement to Response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors". [CP-200901307]

2.S Letter Logged TXX-09126 dated October 12, 2009, Supplement to Response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors". [CP-200901396]

2.T Letter Logged TXX-08141 dated November 26, 2008, Supplement to Response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors". [CP-200801606]

2.U Letter Logged TXX-08095 dated August 28, 2008, Supplement to Response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors". [CP-200800901]

4.3 Comanche Peak SmartForms (Corrective Action Program Documents)

3.A SMF-2001-002201-00: Track activities associated with NRC Generic Safety Issue (GSI)-191, "Assessment of Debris Accumulation on PWR Sump Performance".

3.B SMF-2002-001952-00: Doors to the Steam Generator Compartments could adversely effect the containment and ECCS design functions if closed in MODES 1-4.

3.C SMF-2002-003029-00: Removal of El. 808 Transfer Tube Area Cages.

3.D SMF-2003-002008-01: Response to "NRC Bulletin 2003-01: Potential impact of debris blockage on emergency sump recirculation at pressurized-water reactors".

3.E SMF-2004-002882-00: Errors in screen size in the FSAR, the 1984 paint study and other calculations.

3.F SMF-2004-003972-00: Labeling Program deficiencies - Specification inappropriately voided. Vendor documentation is incomplete. Procedure contains adverse allowances for label materials.

3.G SMF-2005-001869-00: Process SmartForm for GSI-191 Sump Related License Amendments.

3.H SMF-2005-003364-00: Process SmartForm for GSI-191 Sump Related Modifications.

3.I SMF-2007-001267-00: Commodities containing unlogged quantities of aluminum were found in Unit 1 containment.

3.J SMF-2007-002743-00: Close-out activities associated with NRC Generic Safety Issue (GSI)-191, "Assessment of Debris Accumulation on PWR Sump Performance".

3.K SMF-2008-001832: "Fire Extinguishers Inside Containment should be removed (OE25647)".

3.L SMF-2008-001958-00: "Inappropriate exposed materials identified inside the RCS Loop rooms".

3.M SMF-2008-003229-00: "Kaowool backing for joint gap seal found in Unit 1 Containment".

3.N SMF-2008-004082: "Nonconformance Report from Vendor".

3.O SMF-2009-005474: "Engineering Walkdown confirmed presence of Kaowool damming material in Unit 2 Containment".

4.4 Nuclear Energy Institute (NEI) and Electric Power Research Institute (EPRI) Reports and Correspondence

4.A NEI 04-07, "Pressurized Water Reactor Sump Performance Methodology," dated December 2004.
Volume 1 – Pressurized Water Reactor Sump Performance Evaluation Methodology. [aka, the Guidance Report (GR)]
Volume 2 – Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Revision 0, December 6, 2004.

4.B NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," Revision 1, September 2002.

4.C EPRI 1003102, "Guideline on Nuclear Safety-Related Coatings", Revision 1 (Formerly TR-109937) Final Report, November 2001.

4.D EPRI 1011753, "Design Basis Accident Testing of Pressurized Water Reactor Unqualified Original Equipment Manufacturer Coatings", Final Report,

September 2005.

4.E EPRI 1014883, Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level I Coatings Final Report, August 2007.

4.F EPRI 1014884, Plant Support Engineering: Degradation Research for Nuclear Service Level I Coatings Final Report, September 2007.

4.5 Comanche Peak Nuclear Power Plant Condition Assessments and Scoping

5.A ER-ME-118, "Debris Source Inventory Confirmatory Walkdown Report for Comanche Peak Steam Electric Station - Unit 1", Revision 0.

5.B ER-ME-119, "Report on Comanche Peak Steam Electric Station Unit 2 GSI-191 Debris Source Term Confirmatory Walkdown", Revision 0.

5.C ER-ME-122, "Latent Debris and Supplementary Condition Assessment", Revision 1.

5.D ER-ME-123, "GSI-191 Scoping Study", Revision 0, December 20, 2004.

5.E ER-ME-124, "Evaluation of CPSES Protective Coatings", Revision 0, November 28, 2007.

5.F Supplementary Walkdowns and Condition Assessments
ACTN-MAN-2001-002201-21
ACTN-MAN-2001-002201-40
ACTN-MAN-2001-002201-46
ACTN-MAN-2001-002201-80
ACTN-MAN-2001-002201-94
ACTN-MAN-2007-002743-19

4.6 PWR Owner's Group Topical Reports and Correspondence

6.A WCAP-16406-P-A, Evaluation of Downstream Sump Debris Effects in Support of GSI-191, Revision 1 dated March 2008.

6.B WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in

Containment Sump Fluids to Support GSI-191", Revision 0, February 2006.

6.C WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model", Revision 0 dated May 2007.

6.D WCAP-16596-NP, "Evaluation of Alternate Emergency Core Cooling System Buffering Agents ", Revision 0 dated July 2006.

6.E WCAP-16727-NP, "Evaluation of Jet Impingement and High Temperature Soak Tests of Lead Blankets For Use Inside Containment of Westinghouse Pressurized Water Reactors", Revision 0, November 2007.

6.F WCAP-16793-NP, Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid, Revision 1 dated April 2009

6.G PWROG letter OG-07-270, New Settling Rate Criteria for Particulates Generated in Accordance with WCAP-16530-NP (PA-SEE-0275)

6.H PWROG letter OG-07-408, Responses to NRC Requests for Clarification Regarding WCAP-16530, "Evaluation of Chemical Effects in Containment Sump Fluids to Support GSI-191" (PA-SEE-0275)

6.I* PWROG Letter OG-07-534, "Transmittal of Additional Guidance for Modeling Post-LOCA Core Deposition with LOCADM Document for WCAP-16793-P," December, 14,2007

6.J PWROG Letter OG-08-64, Transmittal of LTR-SEE-I-08-30, "Additional Guidance for LOCADM for Modification to Aluminum Release" for Westinghouse Topical Report WCAP-16793-NP, "Evaluation of Long Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid" (PA-SEE-0312) February 8, 2008.

6.K WCAP-17057-P, "GSI-191 Fuel Assembly Test Report for PWROG," March 2009.

4.7 Comanche Peak GSI-191 Analyses and Testing

7.A Alion Science and Technology

7.A.1 ALION-REP-CPSES-2803-002, Comanche Peak: Characterization of Events That May Lead to ECCS Sump Recirculation, Revision 1 dated December , 2007. [VDRT-3448927]

7.A.2 ALION-CAL-TXU-2803-03, Comanche Peak Recirculation Sump Debris Generation Calculation, Revision 2 dated June 4, 2008. [VDRT-3543224]

7.A.3 ALION-CAL-TXU-2803-04, Comanche Peak Reactor Building GSI-191 Debris Transport Calculation, Revision 1 dated December 20, 2007. [VDRT-3448917]

7.A.4 ALION-CAL-TXU-2803-05, Comanche Peak GL 2004-02 Recirculation Sump Head Loss Analysis, Revision 0 dated August 30, 2005. [VL-05-002197]

7.A.5 ALION-CAL-TXU-2803-06, "Summary of Debris Generation and Debris Transport Results", Revision 1 dated June 4, 2008. [VDRT-3543230]

7.A.6 ALION-REP-LAB-2532-95, "Debris Settling Velocity Testing Report", Rev. 1 [VL-07-001293]

7.A.7 ALION-REP-LAB-2532-96, "Debris Tumbling Velocity Testing Report", Rev. 1 [VL-07-001296]

7.A.8 ALION-REP-LAB-2532-97, "Debris Interceptor Testing Report", Rev. 1 [VL-07-001297]

7.A.9 ALION-REP-TXU-2803-21, "Debris Transport and Interceptor Testing Report", Rev. 1 [VL-07-001298]

7.A.10 ALION-REP-TXU-2803-22: "TXU MinK Material Characterization Report (SEM)", Revision 0 [VL-07-001299]

7.A.11 ALION-LAB-REP-TXU-4464-02, TXU Paint Chip Characterization, Revision 0 [VL-07-001897]

7.A.12 ALION-REP-TXU-4464-03, "Comanche Peak Low Density Fiberglass Debris Erosion Testing Report", Revision 0 [VDRT-3457167]

7.A.13 ALION-REP-LAB-2352-77, "Erosion Testing of Low Density Fiberglass Insulation", Revision 1, May 25, 2007. [VDRT-3457160]

7.A.14 ALION-REP-TXU-4464-21, Debris Measurement and Examination Test Report for Comanche Peak Steam Electric Station Units 1 and 2 Step # 1", Revision 0, 8/11/08 [VDRT-3575723]

7.A.15 ALION-REP-TXU-4464-22, "Bypass Debris Characterization Report for Comanche Peak Steam Electric Station Units 1 and 2", Revsion 0, 8/11/08 [VDRT-3578173]

7.A.16 ALION-REP-ALION-2806-01, "Insulation Debris Size Distribution for use in GSI-191 Resolution", Revision 3, 4/13/06. [Attached to 7.A.2]

7.A.17 Letter from Jeffrey Poska, Project Manager, Alion Science & Technology, to John Moorehead, Westinghouse Electric Co., dated February 29, 2008, "GSI-191 Refined Analysis, Alion Third Party Review of Calculation ME-CA-0000-5331, GSI-191 Structural Evaluation of Min-K Insulation Cassettes". [VDRT-3469297]

7.A.18 ALION-REP-TXU-2803-07, Comanche Peak CFD Data Analysis in Support of Alden Testing, Revision 0. [VDRT-3553821]

7.A.19 Letter from Tracy Hadaway, Project Engineer, Alion Science & Technology, to Chuck Feist, Luminant, dated November 19, 2008, "GSI-191 Refined Analysis: Debris Generation Supplemental Coatings Table Summary by Coating System ". [VDRT-3641564]

7.B AREVA NP

7.B.1 AREVA NP, Engineering Information Record, Document Identifier 51-9037978-001, Zone of Influence Evaluation for DBA Qualified Coatings at Comanche Peak Nuclear Power Plant, Revision 1, January 19, 2007. [VL-07-000466]

7.C ENERCON

7.C.1 WES002-PR-02, Evaluation of Containment Recirculation Sump Upstream Effects for the Comanche Peak Steam Electric Station, Rev. 0 dated 8/17/05. [VL-05-002190]

7.C.2 WES002-PR-01, Evaluation of Containment Recirculation Sump Downstream Effects for the Comanche Peak Steam Electric Station, Rev. 0 dated 8/17/05.

7.D Keeler & Long PPG

7.D.1 Report 06-0413, Design Basis Accident Testing of Coating Samples from Unit 1 Containment, TXU Comanche Peak SES". [VL-06-002678]

7.E Westinghouse

7.E.1 CN-SEE-05-100, Comanche Peak Sump Debris Downstream Effects Evaluation for ECCS Equipment, Rev. 1 [Westinghouse Proprietary Class 2]. [VDRT-356250]

7.E.2 CN-SEE-05-87, Comanche Peak Sump Debris Downstream Erosion Effects Evaluation for ECCS Valves, Rev. 1 [Westinghouse Proprietary Class 2]. [VDRT-3578384]

7.E.3 CN-CSA-05-19, Comanche Peak Steam Electric Station Units 1 and 2 GSI-191 Downstream Effects – Vessel Blockage Evaluation, Rev. 0 dated . [Westinghouse Proprietary Class 2] [VL-05-002191]

7.E.4 CN-CSA-05-70, Comanche Peak Units 1 and 2 GSI-191 Downstream Effects – Reactor Fuel Blockage Evaluation, Rev.0 [Westinghouse Proprietary Class 2]. [VDRT-3578377]

7.E.5 CN-CSA-05-65, Comanche Peak Units 1 and 2 GSI-191 Downstream Effects Debris Ingestion Evaluation, Rev. 2 [Westinghouse Proprietary Class 2]. [VDRT-3562506]

7.E.6 WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA Qualified/Acceptable Coatings", Revision 0, June 2006. [This work performed under Utilities Service Alliance, Inc. Project Service Agreement No. 2005-11-00]

7.E.7 WCAP-16571-P, Revision 0, "Test of Pump and Valve Surfaces to Assess the Wear from Paint Chip Debris Laden Water for Wolf Creek and Callaway Nuclear Power Plants". [VDRT-3492919]

7.E.8 WPT-17342, GSI-191 Fuel Assembly Debris Loading, dated June 10, 2009. [VDRT-3745404]

7.F Comanche Peak Engineering Evaluations and Calculations

7.F.1 EVAL-2001-002201-04-01, Comanche Peak Comparison to ICET

7.F.2 EVAL-2001-002201-05-01, Upstream Effects

7.F.3 EVAL-2001-002201-06-01, Downstream Effects, Blockage

7.F.4 EVAL-2001-002201-07-01, Downstream Effects, Wear

7.F.5 EVAL-2001-002201-08-01, Downstream Effects, Vessel Blockage

7.F.6 EVAL-2001-002201-09-01, Downstream Effects, Fuel

7.F.7 EVAL-2001-002201-10-01, Debris Generation

7.F.8 EVAL-2001-002201-11-01, Debris Transport

7.F.9 EVAL-2001-002201-12-01, Head Loss

7.F.10 EVAL-2001-002201-14-01, Event Characterization

7.F.11* EVAL-2001-002201-15-00, Evaluate deviations from RG 1.82

7.F.12* EVAL-2001-002201-16-00, Changes to Engineering Specifications and Procedures

7.F.13* EVAL-2001-002201-17-00, Changes to Containment Inspection and Surveillance Procedures

7.F.14* EVAL-2001-002201-18-00, Capturing the information that was used as design input for analyses, modifications, or other aspects of this effort to ensure that the necessary configuration can and will be maintained.

7.F.15 EVAL-2001-002201-19-00, Evaluate antisweat insulation specifications and materials for debris characteristics

7.F.16 EVAL-2001-002201-20-00, Evaluate mechanical seals on ECCS and CT Pumps for Leakage requirements and for the effect of failure of the seal and disaster bushing.

7.F.17 ME-CA-0000-5066, Calculation of Minimum Flood Level in the Containment Following a Large Break LOCA, Small Break LOCA and MSLB, Revision 4.

7.F.18 ME(B)-389, RWST Setpoints, Volume Requirements, and time depletion analysis, Revision 11

7.F.19 ME(B)-325, Head Losses between Containment Sumps and RHR Pumps During Recirculation and NPSHa, Revision 3

7.F.20 ME-CA-0232-5416, Evaluation of GSI-191 Impacts on the Containment Spray System Performance, Revision 0

7.F.21 ME-CA-0232-4006, NPSHa for Containment Spray Impellers Using Nominal Test Data, Revision 2

7.F.22 RXE-LA-CPX/0-100, Time to Return Containment to Ambient Temperature Following MSLB and LOCA, Revision 0.

7.F.23 RXE-LA-CPX/0-101, Post LOCA Long Term Cooling Calculation for CPNPP Considering Particulates and Chemical Debris, Revision 0.

7.F.24 ME-CA-0000-5331, GSI-191 Structural Evaluation of Min-K Insulation Cassettes, Revision 1.

7.F.25* EVAL-2007-002743-11, Evaluate crediting air partial pressure in containment for NPSHa margin.

7.F.26 EVAL-2004-003972-01-02, Estimate of Unit 1 Labels.

7.F.27 EVAL-2004-003972-12-01, Unit 2 labels after 2RF10.

7.F.28 EVAL-2004-003972-13-01, Unit 1 labels after 1RF12.

7.F.29* EVAL-2007-002743-12, Evaluate the reactor vessel insulation materials for emergency sump performance.

7.F.30 ME-CA-0000-5319, Reactor Cavity Fill Rate, Revision 0

7.F.31* ME-CA-0000-5386, Estimated Containment Flow Distribution at Elevation 808', Revision 0

7.F.32 ME-CA-0000-5415, Containment Sump Chemical Model & Effects Using Current &Alternate Buffering Agents, Revision 1

7.F.33 ME-CA-0232-5018, Analysis of pH for containment spray and containment sump solution, Revision 1

7.F.34 ME-CA-0232-5363, Calculation of Approach Velocities for Containment Emergency Sump Debris Interceptors Rate, Revision 0

7.F.35 ME-CA-0232-5395, Unit 1 and Unit 2 Aluminum Inside Containment, Revision 2

7.F.36* RXE-LA-CPX/0-18, Ultimate Heat Sink and Maximum Sump temperature, Revision 8

7.F.37 EVAL-2005-003364-22, Strainer Debris Bypass Testing - Evaluate data.

7.F.38 EVAL-2001-002201-24, Evaluate a scenario where debris laden containment sump water erodes the chemical injection eductors sufficiently to impact the Containment Spray Pumps.

7.F.39 ME-CA-0000-5424, Evaluate the Impact on the Containment Spray Pumps of Having Chemical Additive Tank Eductor Wear, Revision 0.

7.F.40 RXE-LA-CPX/0-103, Thermal-hydraulic Bases for the Success Criteria & Accident Sequence Event Trees for the CPNPP PRA, Revision 0.

7.F.41 ME(B)-389, RWST Setpoints, Volume Req uirements, and Time Depletion Analysis, Revision 11.

7.F.42 EE-CA-0000-5394, "GSI -191 Evaluation of Radiant Energy Shield (RES) Debris Generation", Revision 1.

7.F.43 ACTN-MAN-2001-002201-81, Identification of flexible tubing material used for RCP lube oil collection system.

7.F.44 ACTN-MAN-2001-002201-83, Determination of RHR Pump Seal Cooler Tube ID.

7.G Corrosion Control Consultants and Labs Inc.

7.G.1 Letter from Jon Cavallo, Vice President, Corrosion Control Consultants and Labs Inc. to Charles Feist, CPNPP, dated September 20, 2007. [VL-07-001829]

4.8. Comanche Peak Strainer Specification, Design, and Testing Documents

8.A Specification

8.A.1 CPES-M-2044, Emergency Sump Suction Strainers, Revision 5

8.A.2 2323-MS-31, Reflective Insulation, Revision 2

8.B PCI Hydraulic Calculations and Reports

8.B.1* TDI-6004-00, Sure-Flow Suction Strainer Qualification Report, Rev. 3 dated 8/19/2008 [VDRT-3578275]

8.B.2* TDI-6004-01, SFS Surface Area, Flow and Volume Calculation, Revision 1, dated 9/25/2006 [VL-07-001031]

8.B.3* TDI-6004-02, Debris Allocations Design Inputs for Test Plan, Revision 3, dated 9/26/2006 [VL-07-001032]

8.B.4* TDI-6004-03, Core Tube Design Comanche Peak Steam Electric Station, Revision 0, dated 7/27/2006 [VL-07-001033]

8.B.5* TDI-6004-04, Debris Weights on Modules, Revision 1, dated 4/24/2007 [VL-07-001034]

8.B.6 TDI-6004-05, Clean Head Loss Comanche Peak Steam Electric Station, Revision 2, dated 9/27/2006 [VL-06-002448]

8.B.7 TDI-6004-06, Total Head Loss Comanche Peak Steam Electric Station, Revision 2, dated 8/19/2008 [VDRT-3578261]

8.B.8 TDI-6004-07, Vortex, Air Ingestion & Void Fraction - Comanche Peak Steam Electric Station, Revision 1, dated 8/19/2008 [VDRT-3578267]

8.B.9* TDI-6004-08, Floor Drain Design and Qualification Report, Revision 1, dated 9/26/06 [VL-06-002449]

8.B.10* SFSS-TD-2007-002, Suction Flow Control Device - SFCD -Principles and Clean Strainer Head Loss. Rev. 0 [Proprietary][VDRT-3521251]

8.B.11* SFSS-TD-2007-003, SURE-FLOW Suction Strainer Vortex Issues, Rev. 0. [Proprietary] [VDRT-3521256]

8.C Automated Engineering Services Corp. (AES) Calculations - Structural

8.C.1 AES Document No. PCI-5472-S01, Structural Evaluation of Emergency Sump Suction Strainers, Revision 3, dated 3/23/2007 [VL-07-001035]

8.C.2 AES Document No. PCI-5472-S02, Structural Evaluation of the Reactor Cavity Floor Drain Strainers, Revision 0, dated 9/27/2006 [VL-06-002562]

8.D PCI and AREVA NP Reports - Testing

8.D.1 AREVA NP, Engineering Information Record, Document Identifier 51-9009544-002, Test Plan for Comanche Peak 1 & 2 Strainer Performance Testing, dated March 2006 [VL-07-001805]

8.D.2 AREVA NP, Engineering Information Record, Document Identifier 51-9024342-001, Comanche Peak 1 & 2 Strainer Perfomance Test Report, dated August 2006 [VL-06-002591]

8.D.3 AREVA NP, Engineering Information Record, Document Identifier 51-9022445-000, Comanche Peak Debris Bypass Percentages, dated September 2006 [VL-06-002590]

8.D.4 SFSS-TD-2007-004, Sure-Flow® Suction Strainer - Testing Debris Preparation and Surrogates, Rev. 4 dated 1/16/2009 (Proprietary) [VDRT-3787427] and SSFS-TD-2007-004 Sure-Flow® Suction Strainer - Testing Debris Preparation and Surrogates, Supplement 1, Revision 1 dated August 26, 2009 (Proprietary) [VDRT-3787434].

8.D.5 TDI-6024-02, Debris Allocations - Design Inputs for Test Plan dated 2/28/08. [VDRT-3521267]

8.D.6 AREVA NP, Engineering Information Record, Document Identifier 63-9073071-001, Test Plan [VDRT-3521217]

8.D.7 Areva NP, Engineering Information Record, Document Identifier 51-9016432-000, Strainer Test Results for Comanche Peak 1 & 2, dated March 2006. [included in 8.D.8]

8.D.8 AREVA NP, Engineering Information Record, Document Identifier 66-9078989-000, Comanche Peak Test Report for ECCS Strainer Performance Testing, dated July 2008. [included in 8.D.9]

8.D.9 EC-PCI-CP-6004-1005, AREVA Document No. 66-9078989-000 "Comanche Peak Test Report for ECCS Strainer Performance Testing.[VDRT-3572600]

8.D.10 AREVA NP, Engineering Information Record, Document Identifier 32-9079948-000, Comanche Peak Flume Configuration Simulation, dated July 1, 2008. [Proprietary] [VDRT-3643423]

4.9 NRC Regulations, Regulatory Guidance, and Reports

9.A 10CFR50.46, Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors.

9.B 10CFR50.59, Changes, tests and experiments.

9.C 10CFR50.71, Maintenance of records, making of reports.

9.D 10CFR50, Appendix A, General Design Criteria for Nuclear Power Plants
Criterion 4 - Environmental and Dynamic Effects Design Bases
Criterion 35 - Emergency Core Cooling
Criterion 38 - Containment Heat Removal

9.E 10CFR100, Reactor Site Criteria

9.F Regulatory Guide 1.82, "SUMPS FOR EMERGENCY CORE COOLING AND CONTAINMENT SPRAY SYSTEMS", Revision 0, June 1, 1974.

9.G Regulatory Guide 1.82, "WATER SOURCES FOR LONG-TERM RECIRCULATION COOLING FOLLOWING A LOSS-OF-COOLANT ACCIDENT, Revision 3, November 2003.

9.H Acceptance Criteria of NRC Standard Review Plan, Section 3.6.2, Determination of Break Locations and Dynamic Effects Associated with the Postulated Rupture of Piping. Also Branch Technical Position MEB 3-1, Postulated Breaks and Leakage Locations in Fluid System Piping Outside Containment.

9.I NUREG/CR-6916, Hydraulic Transport of Coating Debris, December 2006.

9.J RG 1.54, Service Level I, I, And III Protective Coatings Applied to Nuclear Power Plants, Revision 1, July 2000.

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

9.L NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris", October 1995.

9.M RG 1.1 Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps [Safety Guide 1 dated 11/2/70]

9.N NUREG/CR-6885/LA-UR-04-5416, "Screen Penetration Test Report," dated October 2005.

9.O NUREG/CR-3792, An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions. September 1982.

9.P NUREG/CR-6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," U.S. Nuclear Regulatory Commission, February 2003.

9.Q NUREG/CR-2982, Buoyancy, Transport, and Head Loss of Fibrous Reactor Insulation, Revision 1, July 1983.

9.R NUREG/CR-6772, "GSI-191: Separate-Effects Characterization of Debris Transport in Water", August 2002.

9.S Regulatory Guide 1.46, Protection Against Pipe Whip Inside Containment, May 1973.

9.T NUREG/CR-6877, Characterization and Head-Loss Testing of Latent Debris from Pressurized-Water-Reactor Containment Buildings, July 2005.

4.10 Los Alamos National Lab

10.A LA-UR-05-0124, Integrated Chemical Effects Test Project: Test #1 Data Report, June 2005.

10.B LA-UR-05-6146, Integrated Chemical Effects Test Project: Test #2 Data Report, dated September 2005

10.C LA-UR-04-5416, "Screen Penetration Test Report," dated November 2004.

10.D* LA-UR-01-6640, Development of Debris-Generation Quantities in Support of the Parametric Evaluation, November 2001.

4.11 General Electric BWR Owners' Group

11.A Report NEDO-32686, Rev. 0, "Utility Resolution Guidance for ECCS Suction Strainer Blockage".

4.12 Industry Codes and Standards

12.A ASTM D 3911-03, Standard Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design Basis Accident (DBA) Conditions..

12.B ASTM D 5144-00, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants.

12.C ASTM D 5163-05a, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant.

4.13 Comanche Peak Specifications

13.A* Specification Piping and Equipment Insulation, 2323-MS-30, Rev. 2.

13.B* Reflective Insulation Specification No. 2323-MS-31, Rev. 2.

13.C* Shop Fabricated Piping Specification No. 2323-MS-43B, Rev. 9

13.D* Labeling and Signage Specification CPES-M-2045, Rev. 1

4.14 Comanche Peak Procedures

14.A STA-692, Maintenance Coatings Program, Revision 4.

14.B EPG-5.01, Engineering Support - Protective Coatings Program, Revision 1.

14.C* STA-697, Containment Material Control, draft.

14.D* STA-699, Configuration Management Program, Revision 0.

14.E* STA-425, Materials Control, Revision 0, PCN-6.

14.F* STA-606, Control of Maintenance and Work Activities, Revision 29.

14.G STA-607, Housekeeping Control, Revision 19, PCN-2.

14.H* STA-626, Chemical/Consumable Control Program, Revision 9.

14.I* STA-661, Non-plant Equipment Storage and Use Inside Seismic Category I Structures, Revision 4.

14.J* STA-605, Clearance and Safety Tagging, Revision 18.

14.K* STA-618, Station Labeling Control, Revision 7.

14.L* STA-620, Containment Entry, Revision 12, PCN-6.

14.M* STA-602, Temporary Modifications and Transient Equipment Placements, Revision 16.

14.N STA-625, Foreign Material Exclusion, Revision 6, PCN-2.

14.O* STA-690, Erecting and Control of Scaffolding, Revision 3, PCN-12.

14.P* STA-612, System Cleanness Control and Cleaning, Revision 4, PCN-05.

14.Q* STA-689, Lubricant Control Program, Revision 1, PCN-01.

14.R* STA-716, Modification Process, Revision 17, PCN-02.

4.15 TRANSCO PRODUCTS INC.

14.A Transco Products Inc., "Experimental 'Measurements on the Characteristics of Flow Transport, Pressure Drop, and Jet Impact on Thermal Insulation," NRC Guide 1.82, Test Report No. ITR-92-03N, Revision 1, 9/30/99.

* Denotes references GSI-191 related documents not directly referenced in this report.

Section 5.0 NRC REQUEST FOR ADDITIONAL INFORMATION

The following is the response to the NRC request for additional information dated July 15, 2009 [Ref. 1.K].

1. The Min-K at Comanche Peak Steam Electric Station, Units 1 and 2 (CPSES) is encased within stainless steel cassettes. The supplemental response stated that the cassettes are equivalent to Transco reflective metallic insulation (RMI), which has a spherical-equivalent zone of influence (ZOI) of 2.0 D listed in the approved guidance report (Nuclear Energy Institute (NEI) 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology"). The response stated that the maximum steel thickness was to be 0.125 inches. A minimum thickness was not provided. The supplemental response indicated that the cassette thickness was 0.50 inches while the Transco RMI tests used samples with thicknesses ranging between 0.024 and 0.062 inches. It is not clear that the Transco RMI destruction tests bound the Min-K cassettes. There is no direct comparison of the properties of the RMI cassettes and the Min-K cassettes. Because Min-K is known to result in high head losses, non-conservative treatment of the generation of this type of debris calls into question the overall conservatism of the Luminant Generation Company LLC's (licensee's) evaluation.

    a. Please provide an evaluation that justifies that the Min-K cassettes are at least as structurally robust as the RMI cassettes, including any influence that the Min-K or RMI foils would have on the structure.

    b. Please address whether the testing methodology considered failure mechanisms that could apply to Min-K insulation, but may not adversely affect RMI or may not have been considered during the original RMI testing. For example, could a cassette located further than the equivalent to 2D from the break be ejected from its component, impact a nearby object, break open, and release the particulate insulation?

    c. Please state what jet impingement angles were considered in the ZOI testing.

    d. Please explain how the jet to target scaling was taken into account. Please explain whether the centerline jet pressure impacted the entire target or was only a portion of the target impacted by the predicted pressure. Having the target too close to the nozzle could result in a significantly non-conservative test.

Response to RAI 1:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.b.1.2 for the additional information requested.

2. CPSES uses lead blankets with fiberglass covers for shielding within containment. The blankets were tested by Westinghouse to determine an appropriate lOI for destruction and size distribution. The testing estimated the amount of lead fibers and the amount of fiberglass covering that would be damaged within various lOis. Because the lead would likely not transport, it will not be addressed further by the U.S. Nuclear Regulatory Commission (NRC) staff. However, the fiberglass cover could potentially contribute to debris loading on the strainer. ZOI testing for CPSES was conducted by Westinghouse and documented in report WCAP-16727-NP, "Evaluation of Jet Impingement and High Temperature Soak Tests of Lead Blankets for Use Inside Containment of Westinghouse Pressurized Water Reactors," dated February 2007. The NRC staff has reviewed a similar Westinghouse report, WCAP-16710, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON Insulation, for Wolf Creek and Callaway Nuclear Operating Plants," dated October 2007, and has reason to believe that similar test practices were used for both reports. CPSES should address the following questions regarding prototypicality of the WCAP-1671 0 testing, or explain why these questions are not applicable to CPSES. Alternatively, the licensee may choose to demonstrate that the debris source term would not be significantly impacted even if no credit is taken for WCAP-16727. Establishing the validity of the ZOI assumptions is very important to the validity of the overall approach to determining head loss since the amount of debris assumed to be generated is very sensitive to the assumed ZOI.

   a. Although the American National Standards Institute (ANSI)/American Nuclear Society (ANS) standard predicts higher jet centerline stagnation pressures associated with higher levels of subcooling, it is not intuitive that this would necessarily correspond to a generally conservative debris generation result. Please justify the initial debris generation test temperature and pressure with respect to the plant-specific reactor coolant system (RCS) conditions, specifically the plant hot-and cold-leg operating conditions. If ZOI reductions are also being applied to lines connected to the pressurizer, then please also discuss the temperature and pressure conditions in these lines. Please explain whether any tests were conducted at alternate temperatures and pressures to assess the variance in the destructiveness of the test jet to the initial test condition specifications. If so, provide that assessment.

b. Please describe the jacketing systems used in the plant for which the testing was conducted and compare those systems to the jacketing/insulation systems tested. Please justify whether the tested jacketing system adequately represented the plant jacketing system. The description should include differences in the jacketing, banding, and attachment systems used for piping and other components for which the test results are applied. At a minimum, the following areas should be addressed:

i. How did the characteristic failure dimensions of the tested jacketing compare with the effective size of the jet at the axial placement of the target? The characteristic failure dimensions are based on the primary failure mechanisms of the jacketing system (e.g., for a stainless steel jacket held in place by three latches where all three latches must fail for the jacket to fail, then all three latches should be effectively impacted by the pressure for which the ZOI is calculated). Applying test results to a ZOI based on a centerline pressure for relatively low nozzle-to-target spacing would be non-conservative with respect to impacting the entire target with the calculated pressure.

ii. Was the jacketing system used in the testing of the same general manufacturing materials and manufacturing process as the insulation used in the plant? If not, what steps were taken to ensure that the general strength of the insulation system tested was conservative with respect to the plant insulation? For example, it is known that generally two very different processes were used to manufacture calcium silicate insulation, whereby one type readily dissolves in water but the other type dissolves much more slowly. Such manufacturing differences could also become apparent in debris generation testing as well.

iii. The information provided should also include an evaluation of scaling the strength of the jacketing system to the tests. For example, a latching system on a 30-inch pipe within a lOI could be stressed much more than a latching system on a 10-inch pipe in a scaled lOI test. If the latches used in the testing and the plants are the same, the latches in the testing could be significantly under-stressed. If a prototypically-sized target were impacted by an undersized jet it would similarly be under-stressed. Evaluations of banding, jacketing, rivets, screws, straps, etc., should be made. For example, scaling the strength of the jacketing was discussed in the Ontario Power Generation report on calcium silicate debris generation testing.

iv. The testing discussed open and closed-back tests. How did this compare to plant conditions, which testing was used for the CPSES evaluation, and how did this compare to the plant? For example, blowing pieces of debris through an open area in the test condition will not result in further debris fragmentation, whereas blowing debris through a congested containment could easily result in increased fragmentation.

v. If the restraints in the test condition were weaker than the plant condition, the test characterization would be non-conservative for the plant condition. The test debris would be blown away from the high-pressure region of the jet in larger (or intact) pieces, whereas the plant material would be held in the high-pressure region of the jet for a longer period of time by the stronger restraints and consequently be fragmented to a greater degree. This non-prototypicality appears to be the case based on the licensee's statement that the plant material is more securely attached than the test material. Please justify the conservatism of the restraints in the test condition.

c. There are relatively large uncertainties associated with calculating jet stagnation pressures and lOis for both the test and the plant conditions based on the models used in the WCAP reports. Please explain what steps were taken to ensure that the calculations resulted in conservative estimates of these values. Please provide the inputs for these calculations and the sources of the inputs.

d. Please describe the procedure and assumptions for using the ANSI/ANS-58-2-1988 standard, "Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Rupture," to calculate the test jet stagnation pressures at specific locations downrange from the test nozzle. Please include discussion of the following points.

i. In WCAP-16710-P, the analysis was based on the initial condition of 530 degrees Fahrenheit (^{0}F) whereas the initial test temperature was specified as 550 of. Was this similar for the WCAP-16727 testing? If so, please evaluate the discrepancy.

ii. Please explain whether the water subcooling used in the analysis that of the initial tank temperature or whether it was it the temperature of the water in the pipe next to the rupture disk. Test data indicated that the water in the piping had cooled below that of the test tank.

iii. The break mass flow rate is a key input to the ANSI/ANS-58-2-1988 standard. Please explain how the associated debris generation test mass flow rate was determined. If the experimental volumetric flow was used, then please explain how the mass flow was calculated from the volumetric flow, given the considerations of potential two-phase flow and temperature-dependent water and vapor densities. If the mass flow was analytically determined, then please describe the analytical method used to calculate the mass flow rate.

iv. Noting the extremely rapid decrease in nozzle pressure and flow rate illustrated in the test plots in the first tenths of a second, please explain how the transient behavior was considered in the application of the ANSI/ANS-58-2-1988 standard. Specifically, did the inputs to the standard represent the initial conditions or the conditions after the first extremely rapid transient (e.g., one-tenth of a second)?

v. Given the extreme initial transient behavior of the jet, please justify the use of the steady-state ANSI/ANS-58-2-1988 standard jet expansion model to determine the jet centerline stagnation pressures rather than experimentally measuring the pressures.

e. Please describe the procedure used to calculate the isobar volumes used in determining the equivalent spherical ZOI radii using the ANSI/ANS-58-2-1988 standard. Please include discussion of the following points:

i, What were the assumed plant-specific (RCS) temperatures and pressures and break sizes used in the calculation? Note that the isobar volumes would be different for a hot-leg break than for a cold-leg break since the degrees of subcooling is a direct input to the ANSI/ANS-58-21988 standard. This affects the diameter of the jet. Note that an undercalculated isobar volume would result in an under-calculated ZOI radius.

ii. Please explain the calculational method used to estimate the plant specific and break-specific mass flow rate for the postulated plant loss-of coolant accident (LOCA), which was used as input to the standard for calculating isobar volumes.

iii. Given that the degree of subcooling is an input parameter to the ANSI/ANS-58-2-1988 standard and that this parameter affects the pressure isobar volumes, please explain what steps were taken to ensure that the isobar volumes conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections. Were multiple break conditions calculated to ensure a conservative specification of the ZOI radii?

f. Please describe the test apparatus, specifically including the piping from the pressurized test tank to the exit nozzle including the rupture disk system. Please also address the following points.

i. Based on the temperature traces in the reviewed test reports, it is apparent that the fluid near the nozzle was colder than the bulk test temperature. How was the fact that the fluid near the nozzle was colder than the bulk fluid accounted for in the evaluations?

ii. How was the hydraulic resistance of the test piping which affected the test flow characteristics evaluated with respect to a postulated plant-specific LOCA break flow where such piping flow resistance would not be present?

iii. What was the specified rupture differential pressure of the rupture disks?

g. WCAP-16710-P discusses the shock wave resulting from the instantaneous rupture of piping. Please discuss the following as they apply to the WCAP-16727 testing.

i. Was any analysis or parametric testing conducted to get an idea of the sensitivity of the potential to form a shock wave at different thermalhydraulic conditions? Were temperatures and pressures prototypical of pressurized-water reactor (PWR) hot legs considered?

ii. Was the initial lower temperature of the fluid near the test nozzle taken into consideration in the evaluation? Specifically, was the damage potential assessed as a function of the degree of subcooling in the test initial conditions?

iii. What is the basis for scaling a shock wave from the reduced-scale nozzle opening area tested to the break opening area for a limiting rupture in the actual plant piping?

iv. How is the effect of a shock wave scaled with distance for both the test nozzle and plant condition?

h. Please provide the basis for concluding that a jet impact on the tested geometric configuration is conservative with respect to potential installed configurations within the plant. Please justify whether all banding mechanisms of lead blankets used in the plant provide the same measure of protection against a LOCA jet as those of the configuration that was tested.

i. Please provide the expected characteristics of the lead blanket cover fines and provide information that shows that the debris was prepared such that the surrogate characteristics were in accordance with the expectation of the postaccident behavior of these materials. It was stated that the debris surrogate was a fiber cover run through a leaf shredder. What were the resulting debris characteristics? The other fine fibrous debris was stated to be further shredded after putting it through a leaf shredder.

Response to RAI 2:

The generic portion of this request are being addressed by the PWR Owner's group. Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The CPNPP specific portion (2.b.d, 2.b.e, 2.h and 2.I) is addressed in Section 3.b.1.4.

3. The November 26, 2008, supplemental response identifies that an average particle size for Min-K of 29.8 microns was assumed. This particle size was based in part on measurements with a scanning electron microscope. Based on information from NRC audits of other licensees and a review of the Min-K material safety data sheets, the NRC staff understands that the 0.1-micron distance (taken as the characteristic size for Min-K in NEI 04-07) referred to by the licensee as an air space between adjacent particles is actually the size of elementary particles of titanium dioxide. Similarly, elementary particles of fumed silica could be in the range of < 5 m, based on information from previous reviews. It is not clear that the sample of Min-K taken by the licensee is representative of Min-K debris after being destroyed by a LOCA jet, particularly given that the 20 ZOI will lead to stagnation pressures of approximately 114 pounds per square in gauge (psig). Please justify whether the material for which the licensee made a scanning electron microscope observation is representative of Min-K destroyed by a LOCA jet of 114 psig.

Response to RAI 3:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.c.1.2 for the requested information.

4. On page 68 of the November 26, 2008, supplemental response, it appeared that some miscellaneous debris materials were found to delaminate or be reduced to fibrous pulp after being boiled, and that these materials were subsequently excluded from head loss testing on that basis. Please provide an adequate basis for excluding this material from the head loss testing, considering the following information:

   a. Post-LOCA conditions may exist for which the containment pool will not reach (atmospheric) boiling temperatures. Even if the containment pool were to reach or exceed 212 of, Section 3.5.2.3 of the safety evaluation (SE) of NEI 04-07 indicates that labels and miscellaneous materials that could degrade under post LOCA conditions should be modeled as debris in their degraded form (e.g., using an equivalent mass of latent fiber to model labels that fail to a fibrous form), rather than excluded from head loss testing due to degradation.

b. Please clarify whether the material excluded from head loss testing based upon its degradation under boiling conditions was accounted for through the allocation of an appropriate strainer sacrificial surface area.

Response to RAI 4:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.b.3 and 3.f.3.3 for the requested information.

5. During the NRC staff evaluation of the sacrificial area determination and miscellaneous debris treatment, inconsistencies and uncertainties were identified with regard to the categorization criteria, assumptions, and treatment in testing/analysis of miscellaneous debris (labels/tags). These estimates and assumptions playa role in the sacrificial area determination and final strainer debris load. As described in Section 3.b.3, Labels and Tags, of the November 26, 2008, supplemental response, three classifications for labels were selected: Acceptable Labels, Qualified Labels, and Unacceptable Labels. Please provide the quantity of each label type present in the CPSES containments. In addition please discuss the final treatment of each label category with regard to head loss testing and emergency core cooling system (ECCS) strainer debris load. Please clarify the methodology used to estimate the sacrificial screen area and how this area was utilized in relation to head loss testing/net positive suction head analysis.

Response to RAI 5:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.b.3 for the requested information.

6. Please describe the testing performed to support the assumption of 10 percent erosion of fibrous debris pieces in the containment pool. Please specifically include the following information:

   a. Please describe the test facility used and demonstrate the similarity of the flow conditions (velocity and turbulence), chemical conditions, and fibrous material present in the erosion tests to the analogous conditions applicable to the plant condition.

   b. Please provide specific justification for any erosion tests conducted at a minimum tumbling velocity, if debris settling was credited in the test flume for velocities in excess of this value.

   c. Please identify the duration of the erosion tests and how the results were extrapolated to the sump mission time.

Response to RAI 6:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. In that meeting, a comparison of the CPNPP pool to the erosion test flume was provided in the presentation "Preliminary Assessment of Containment Pool with respect to Erosion Testing". It concluded that:

- The velocity in the flume during the erosion tests was approximately double the average velocity for which non-transporting pieces of small fiberglass in the Comanche Peak pool would be exposed.

- The turbulence in the flume during the erosion tests was approximately equal to the average turbulence for which non-transporting pieces of small fiberglass in the Comanche Peak pool would be exposed.

See revised Section 3.e.2 for the requested information.

As noted in Section 3.e.2, the erosion testing reports have been provided to the NRC in response to the request made to multiple utilities. Alion Science and Technology may submit additional information concerning erosion testing to the NRC on behalf of CPNPP and other utilities.

7. The November 26,2008, supplemental response indicates on page 43 that some of the debris assumed to be blown to upper containment is not assumed to be washed down subsequently. Please provide the following additional information as a basis for this assumption:

   a. Please identify the types of debris and debris sizes for which retention credit was taken and quantify the credit taken.

   b. Please describe the extent and continuity of the grating where debris capture is credited, and provide a percentage of the cross-sectional area below these breaks where grating is installed.

   c. Please provide adequate basis to justify any credit for small pieces of debris being held up on grating. The Drywell Debris Transport Study cited by the supplemental response considered the retention of small fibrous debris pieces on gratings in upper containment and recommended that no retention credit should be allowed for debris fragments that are smaller than openings in floor grating.

Response to RAI 7:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.e.1.1 and below.

Background

In the Comanche Peak debris transport calculation [Ref. 7.A.3], drywell debris transport study (DDTS) test data was used to take credit for small pieces of fiberglass being held up on grating as discussed in NUREG/CR-6369 [Ref. 9.K]. In the NUREG/CR-6369 testing, 1.5" pieces of fiberglass (obtained directly from blast testing) were placed on 1" × 4" grating and subjected to containment sprays with a flow rate per unit area of 5 gpm/ft^2 for a total of 30 minutes [Ref. 9.K, Volume 2]. The results of the testing showed a washdown fraction between 38% and 47%. For Comanche Peak, the grating size is approximately the same (1-¼" × 3/16" bearing bars spaced 1-3/16" on centers and crossbars spaced not more than 4" on centers), and the maximum two train spray flow rate is 15,040 gpm. Since the containment cross sectional area for Comanche Peak is 14,314 ft2 and the maximum spray flow from 272 Train A and 273 B spray nozzles from Region A above

Elevation 905' is 10.900 gpm, the average spray flow rate per unit area is approximately 0.76 gpm/ft^2, which is significantly less than the flow rate used for the NUREG/CR-6369 washdown tests. Therefore, it was considered to be reasonable and conservative to use a washdown fraction of 50% for small fiberglass through grating. The fiberglass fines were conservatively assumed to have 100% washdown transport with no retention on structures or grating. Since large pieces of debris would not pass through grating or the hydrogen vents and drain holes, and this debris would also not be readily transported across the concrete floor in upper containment, the washdown fraction for large pieces was considered to be negligible.

A similar issue was brought up during the onsite audit of the Indian Point Unit 3 (IP-3) GSI-191analyses conducted by the NRC from December 3, 2007 through December 6, 2007 [Ref. 1.O]. During the audit, the NRC verbally expressed concerns regarding the applicability of using the NUREG/CR-6369 test data for crediting hold up of small pieces of fiberglass on grating. Specifically, they questioned, 1) the applicability of the test results for long term spray operation at IP-3 since the tests were terminated after 30 minutes, 2) the applicability of thetest results for debris washed from a concrete floor over the edge of a grated opening since the spray flow would be more concentrated in the regions where spray flow spills over the edge of a concrete floor, and 3) whether debris washed through an upper level of grating would be captured with the same efficiency by a second level of grating as it is washed down.

These concerns will be addressed as applicable to debris transport at Comanche Peak in the following analysis.

Applicability of Tests Results for Long Term Spray Operation

It is possible that some additional washdown could occur after 30 minutes. However, NUREG/CR-6369 states that based on visual observation, the majority of the washdown occurred within the first 15 minutes. Given this observation, it is not likely that a significantly larger quantity of debris would have been washed down if the test was run longer than 30 minutes. To account for some uncertainty in the testing, however, the observed washdown of 38% to 47% was conservatively rounded up to 50%. Note that the containment spray erosion of fiberglass debris that is retained on grating was addressed separately and included as an additional transport term in the logic trees.

Applicability of Test Results for Debris Washed off of a Concrete Floor through Grating

At the end of the blowdown phase, some of the debris blown to upper containment would land on the grating in upper containment, and some of the debris would land on the concrete operating deck. As the containment sprays pool up and run off the edges of the operating deck, the debris on the operating deck could potentially be transported over the edges of the grating in a higher flow concentration than the direct spray resulting in a higher washdown transport fraction.

In Section 5.5 of the Comanche Peak debris transport calculation, debris landing on the operating deck was assumed to be washed to the RCS loop bays, refueling canal, stairwell, equipment hatch, perimeter openings, and floor drains. It was very conservatively assumed that there would be no retention for the small fiberglass debris washed down to all of these regions with the exception of the RCS loop bays. Based on the spray flow split in upper containment, 27% of the small pieces of fiberglass were determined to transport to the RCS loop bays from upper containment—18% falling directly back into the loop bays at the end of the blowdown phase, and 9% washing to the loop bays off of the concrete operating deck. Of the 27% washed to the RCS loop bays, 17% was determined to wash down with 10% held up on grating. There are a number of grated platforms in the RCS loop bays that were assumed to cover three-quarters of the loop bay area. As shown in Figure 3.e.1.1-1 through Figure 3.e.1.1-3, the actual coverage is approximately 87%.

If the small pieces of debris that are washed off of the concrete floor are assumed to pass directly through the grating without any retention on grating at all, the washdown transport fraction would only increase from 17% to 19% as shown in the following calculation:

$$F_{washdown,\ RCS\ Loop\ Bays\ (small\ fiber)} = 0.18 \quad (1 - 0.87 \quad 0.5) + 0.09 = 0.19 \qquad \text{Equation 1}$$

As discussed later in this analysis, the potential minor increase in the washdown fraction based on less holdup of fiberglass washed off the operating deck into the RCS loop rooms is offset by the conservatisms in the debris transport calculation.

Debris Capture as it is Washed through a Second Level of Grating

Although some of the debris washed down in the RCS loop bays would have to pass through two levels of grating to reach the floor, this was conservatively neglected in the analysis. Since only one level of grating was credited for debris retention, this issue is not applicable to Comanche Peak.

Conservatisms in the Debris Transport Analysis

Although the Comanche Peak grating retention fractions are considered to be a very conservative application of the NUREG/CR-6369 washdown tests, it is acknowledged that there is some uncertainty due to the limited amount of test data available. However, when other conservatisms in the transport analysis are taken into consideration, it can be seen that the uncertainty in the grating retention fractions is easily offset by these conservatisms. The following items were considered: 1) BWROG washdown testing, 2) retention of debris on the concrete floors, 3) retention of debris that has been impinged on walls and structures inside the steam generator compartments.

Limiting Fiberglass Break Cases

The limiting break case with respect to the fiber debris generated was taken from the debris generation calculation Table 9-1 for Comanche Peak [Ref. 7.A.2].

At Comanche Peak, the total quantity of anti-sweat fiberglass generated for Break Loop 4 Hot Leg was determined to be approximately 42 ft^3. The average size distribution for this debris was determined to be approximately 17% fines, 68% small pieces, 7% large pieces, and 8% intact blankets [Ref. 7.A.2]. Considering just the quantity of fines and small pieces, there would be 36 ft^3 of debris with a size distribution of 20% fines and 80% small pieces. The blowdown transport fractions for fines and small pieces of fiberglass are 73% for fines, and 59% for small pieces (see Section 5.4 of the debris transport calculation) [ref. 7.A.3]. Multiplying the blowdown transport fractions by the size distributions shows that a total of approximately 22 ft^3 of small and fine fiberglass debris would be blown to upper containment with a distribution of 23% fines and 77% small pieces.

BWROG Washdown Testing

In order to determine the appropriate blowdown and washdown fractions for the BWR ECCS strainer blockage resolution, the BWR owner's group (BWROG) sponsored testing to measure blowdown and washdown fractions for various scenarios and containment configurations [Ref. 11.A]. For the small fiberglass testing, the debris was generated by shredding pieces of fiberglass and then further breaking it down by exposing the pieces to a steam jet. As discussed in the utility resolution guide (URG), this resulted in a fibrous debris size much finer than expected following a LOCA (up to 67% fines) [Ref. 11.A]. A comparison with the size distributions above shows that the URG distribution is conservative with respect to the Comanche Peak distribution (67% fines for the BWROG washdown testing versus 23% fines in upper containment for the Comanche Peak case discussed above). The individual test results are shown in Volume 3, Appendix E of the URG. Tables 1 and 2 in this appendix show that the average washdown fraction of the debris remaining after the blowdown for a Mark II containment configuration is approximately 43%. Tables 3 and 4 show that the average washdown fraction for a Mark I containment configuration is approximately 70% [Note 1] [Ref. 11.A].

Note 1: The washdown fractions are calculated by dividing the washdown transport (% of initial mass) by 100% minus the blowdown transport (% of initial mass). The debris not transported during the blowdown in these tests is the remaining debris available for washdown

Using the more conservative Mark I washdown fraction of 70% and applying it to Comanche Peak for the fines and small pieces in upper containment shows that the current debris transport results are essentially the same as the alternate approach of applying the BWROG washdown test results (see Figure 3.e.1.1-4 and Figure 3.e.1.1-5). This is a significant finding considering the statement in the URG that the BWROG test results were very conservative [Ref. 11.A].

Retention of Debris on Concrete Floors

One of the significant conservatisms in the Comanche Peak debris transport analysis is the assumption that all debris in upper containment would be washed down to the pool with the exception of a portion of small piece debris held up on grating (i.e. all debris is washed to the various grated hatches and openings without being held up on the concrete floors).

Based on Section 5.5 of the debris transport calculation, a total of 6,606 gpm would land on the concrete operating deck. This spray water would drain to the RCS loop rooms, a stairwell, an equipment hatch, various perimeter openings, and a number of floor drains.

Table 1 shows the flow split and perimeter length for each of these flow paths [Ref. 7.F.31]. Given a pool depth of 0.129 ft (1.5 in) [Ref. 7.F.31], the average water velocity to each region can be calculated as shown in Table 1.

Table 1 – Concrete operating deck spray distribution

Region	Spray Flow (gpm)	Perimeter (ft)	Velocity (ft/s)
RCS Loop Rooms	963.5	13.2	1.3
SE Stairs	219.0	3.0	1.3
Equipment Hatch	3,773.8	51.7	1.3
Perimeter	992.7	13.6	1.3
4" Floor Drains (10)	657.0	10.5	1.1
Total	**6,606.0**	**92.0**	-

The incipient tumbling velocity for small pieces of fiberglass is 0.12 ft/s [Ref.]. Since the flow velocity at the perimeter of each drainage path is high enough to tumble the small fiberglass debris, any pieces located next to the drainage openings would likely be washed down. However, since the approach path to each drainage location is generally radial rather than linear, the water velocity at some distance from the drainage openings would be significantly lower. For example, at just over a foot and a half away from the floor drains, the water velocity would drop below the tumbling velocity for small fiberglass as shown in the following calculation:

$$u = \frac{657.0gpm \cdot 231in^3/gal}{(12in/ft)^3 \cdot 60s/\min} \cdot \frac{1}{10 \cdot 2\pi \cdot 1.5ft} \cdot \frac{1}{0.129ft} = 0.12ft/s$$

Equation 2

Ten percent of the small pieces of fiberglass on the operating deck (657 gpm / 6,606 gpm) were conservatively assumed to be washed down the floor drains. However, since a relatively small amount of fiberglass would be located within 1.5 ft of the drains, the majority of this debris would actually be retained on the operating deck floor. Similarly, a portion of the debris that was assumed to wash to the other drainage openings would also be in low velocity regions on the operating deck floor where it would be retained.

Retention of Debris Impinged on Walls and Structures during Blowdown

Another significant conservatism in the Comanche Peak debris transport analysis is assuming that all debris that is not blown to upper containment would be washed back to the recirculation pool. As discussed in Appendix VI of the SER, approximately 17% of fiberglass fines and small pieces would be captured when the flow makes a 90-degree bend [Ref. 4.A, Volume 2]. Additional debris would also be captured by miscellaneous structures and grating. In the Comanche Peak debris transport analysis, approximately 10% of small fiberglass debris was determined to be captured on walls and miscellaneous structures in the steam generator compartments (see Section 5.4 of the debris transport calculation). Although fiberglass fines would be captured similar to the small pieces, no credit was taken for this capture and all of the small pieces not blown to upper containment were conservatively assumed to be washed back to the containment pool. Since most of the walls and structures in the steam generator compartments are shielded from the containment sprays, the majority of the debris captured on the walls and structures would be retained. Taking credit for this would reduce the overall transport fraction for fiberglass fines by approximately 10% (equivalent to the capture for small fiberglass), as well as a partial reduction in the transport for the small pieces of fiberglass. For the limiting fiberglass debris generation case, the reduction in fiberglass fines transport would result in a reduction of approximately 1 ft^3 at the strainers (42 ft^3 x 17% fines x 10% capture).

Conclusions

An analysis of the NUREG/CR-6369 [Ref. 9.K] washdown test data indicates that although there are some uncertainties in the approach taken, the application of the test data to hold up of small fiberglass debris on grating at Comanche Peak is conservative.

A review of conservatisms taken in various portions of the debris transport analysis and the application of data in the BWROG URG [Ref. 11.A] indicates that the uncertainties associated with the application of the NUREG/CR-6369 washdown test results are more than compensated by the conservative approaches taken in the blowdown and washdown analysis.

8. The November 26, 2008, supplemental response indicates that a significant percentage of small pieces of fiberglass were assumed to transport to the strainers (i.e., 78 percent). In addition, 16-17 percent of large fibrous debris pieces were assumed to transport as well. These analytical assumptions minimized the quantity of settled small and large pieces of

fiberglass that were analytically assumed to erode in the containment pool. However, for the strainer head loss testing conducted by Performance Contracting, Inc. (PCI), the NRC staff considers it likely that a significant fraction of small pieces that were analytically considered transportable actually settled in the test flume rather than transporting to the test strainer. This issue is exacerbated by the fact that the licensee's head loss testing modeled the 1-foot-high debris interceptor in front of the strainer, whereas the debris transport calculation did not credit this interceptor, over which very few fiberglass pieces would be capable of transporting. The head loss testing did not model the erosion of this debris that was analytically assumed to have transported. The licensee's consideration of debris erosion, therefore, appears to be non-conservative, because neither the analysis nor the head loss testing accounted for the erosion of debris that settled during the head loss testing. Please estimate the quantity of eroded fines from small and large pieces of fiberglass debris that would result, had erosion of the settled debris in the head loss test flume been accounted for and justify the neglect of this material in the head loss testing program.

Response to RAI 8:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.f.3.1 and below.

The quantity of fines which were defined prior to the test by acceptable debris transport methodologies are introduced prior to the introduction of other fibrous debris in a flow stream with a higher concentration of particulates in suspension than the plant; which is both unrealistic and very conservative. The test protocol which was discussed at length with the NRC Staff before testing required introduction of the conservatively calculated fiber load as calculated by the debris transport analysis. Consideration of erosion of fiber smalls and larges which may not reach the strainer was not included in the protocol. This is a new issue being raised post-testing.

Erosion of smalls and larges in a prototypical pool would not be significant due to natural agglomeration of tumbling debris; much the same as occurred in the test flume. The larger and more likely a fiber clump is to settle, the less erosion is expected. Since the settling and agglomeration of tumbling debris in a prototypical pool would be significantly greater than in the test flume where debris is sequenced to prevent agglomeration, the erosion would be less than a number of other conservatisms in the analysis and testing. For example, the debris preparation method used for Comanche Peak resulted in a significant quantity small and large fiber batches being introduced as fines.

The PCI fibrous debris used in the large flume test for Comanche Peak as "smalls" was processed through a wood chipper; then screened dry to pass through 1" x 4" grid openings. There were no "fines" removed from this processed debris prior to testing. This fiber class is called "smalls without fines removed".

"Smalls without fines removed" has been measured by PCI to contain ~25% of easily removed loose fines and approximately another 16 % of fines that are loose but within the fiber clumps.

The first 25% was removed using a shaker table with a ½ " x ½" mesh screen for only 90 seconds. The additional 16% was measured from debris classified as "smalls with fines removed" using a shaker table with a ¼" x ¼" mesh screen for 30 minutes. This represents a total of 41% by mass of fines available for erosion when introduced into the large test flume.

A video of smalls being introduced into a flume matching the Comanche Peak head loss test was made. This video was submitted to the NRC under Ref. 2.S. The video shows introduction of the small fibers with the pump on. From the video it appears as though the introduction penetrates about half of the water column. The cloud of debris that gets mixed appears to be fines breaking off of the small fiber introduction.

Therefore, the conservatisms in the debris preparation and test protocol are greater than potential erosion not modeled in the testing.

9. No discussion of transport of small or large pieces of debris was provided for the pool-fill phase of the event. The NRC staff expects that velocities in some parts of typical PWR containment pools could significantly exceed the transport metric for debris in these categories during the pool-fill phase of transport. Flow conditions during the pool-fill phase of the LOCA were not considered by the head loss testing, nor was the potential for some types of debris to enter a non-quiescent containment pool closer than one flume-length away from the strainer due to the effects of blowdown, washdown, and pool-fill transport. The lack of modeling of these transport aspects of the head loss testing may result in a non-prototypical reduction in the quantity of debris reaching the test strainer.

Please provide the technical basis for not explicitly modeling transport modes other than recirculation transport, considering the following points:

a. As shown in Appendix III of the NRC staff's SE on NEI 04-07, containment pool velocity and turbulence values during pool fill up may exceed those during recirculation, due to the shallowness of the pool.

b. The pool-fill phase will tend to move debris from inside the secondary shield wall into the outer annulus away from the break location and nearer to the recirculation sump strainers.

c. Representatively modeling the washdown of some fraction of the debris nearer the strainer than one flume-length away would be expected to increase the quantity of debris transported to the strainer and measured head loss.

Response to RAI 9:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.e.1.1, Section 3.j.2, and below.

Although the turbulence and velocity would be higher at lower pool levels, this would be partially offset since the maximum emergency core cooling system (ECCS) flow rate would be significantly lower during the pool fill phase than during the recirculation phase. The two train ECCS flow rate during the pool fill phase would be 5,784 gpm [Ref. 7.F.30] versus 9,000 gpm for two train operation during recirculation. The maximum containment spray (CT) flow rate would be approximately the same during pool fill and recirculation (15,200 gpm) [Ref.s 7.A.30 and 7.F.21]. However, since the containment sprays drain down to many locations throughout the pool, the containment spray flow would not contribute significantly to debris transport during the pool fill phase.

Following the blowdown phase, as the pool starts to fill, pieces of debris sitting on the floor would be washed from the RCS loop bay through both doors to the area outside the secondary shield wall. Since the floor is flat, the initial sheeting action would be equally likely to carry debris either direction around containment (i.e. either toward the strainer or away from the strainer). The only preferential flow outside the secondary shield wall at this point would be toward the inactive reactor cavity since the cavity entrance does not have a curb around it. Due to flow constrictions in containment, the preferential flow to the reactor cavity would continue throughout the entire pool fill phase [Ref. 7.F.30].

Preferential flow to the strainers during the pool fill up phase would only occur when the water level rises above the top of the 1 ft tall solid debris interceptor around the strainers (long after the point where debris would be easily transported by the initial sheeting flow). Also, since the volume enclosed by the debris interceptors is 1,431 ft^3 [Ref. 7.A.3], at the maximum flow conditions discussed above (20,984 gpm or 46.8 ft^3/s), the preferential flow to the strainers would last for less than a minute. These conditions would not result in significant quantities of small pieces or large pieces of debris washed to the vicinity of the strainers.

For debris in upper containment, given the high containment spray flow, any debris that is in the path of the containment sprays would be likely to wash down very early in the event. Therefore, although a small amount of debris may wash down later in the event, the majority of the debris transported from upper containment would reach the containment pool during the pool fill phase.

Although it is plausible to expect some pieces of RMI and fiberglass debris to be in the vicinity of the strainers at the end of the pool fill phase, the majority of the debris would be scattered throughout the containment pool or concentrated near the entrance to the reactor cavity. Also, since debris would tend to transport away from regions of high turbulence in the vicinity of the break or concentrated spray drainage locations, all of the small and large pieces of debris would settle to the containment floor.

It is reasonable to conclude that there would be some small and large pieces of fiberglass and RMI on the floor in the vicinity of the strainer (more RMI than fiberglass since the quantity of RMI generated would be more than ten times the quantity of fiberglass generated for an LBLOCA [Ref. 7.A.2]). It is also expected that there would be some fine debris in the vicinity of the strainers (both on the floor and in suspension).

10. Sufficient information was not provided in the supplemental responses dated February 29 and November 26, 2008, to provide assurance that the flow conditions simulated in the strainer head loss test flume are prototypical or conservative with respect to the plant conditions. Therefore, please provide plots of velocity and turbulence contours in the containment pool for the bounding computational fluid dynamics cases with respect to

these two parameters that include the entire pool and which are based on the computational fluid dynamics model used in the debris transport analysis. Please also provide close-up plots of the velocity and turbulence contours (which include a numerical scale with units) in the region of the strainer and its immediate surroundings from the computational fluid dynamics model that was used to determine the flume velocities and turbulence levels for head loss testing. Please identify the bounding break scenario that was used to derive the flow parameters (e.g., velocity and turbulence) that were simulated in the head loss test and identify which of the strainers is modeled in the test.

Response to RAI 10:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.f.3.2 and below.

As shown on Figure 3.e.1.2-3, all significant sources of drainage to the surface of the pool were modeled in the CFD analyses. In addition, backflow from floor rains were also modeled in the CFDs. As described in Section 2.1.1 water control features were added to optimize sump performance. Section 3.j.3 described the modifications made to reduce drainage that could cause excessive turbulence in the vicinity of the strainers. See Attachment A, Pictures 3.j.3-2 thru -8.

11. Please discuss any sources of drainage that enter the containment pool near the containment sump strainers (i.e., within the range of distances modeled in the head loss test flume; e.g., 27 feet (ft) based on page 62 of the November 26, 2008, supplemental response or 22 ft based on Attachment D to that response on page 7 of 95). Please identify whether the drainage would occur in a dispersed form (e.g., droplets) or a concentrated form (e.g., streams of water running off of surfaces, drain lines, etc.). Please discuss how these sources of drainage are modeled in the test flume to create a prototypical level of turbulence in the test flume. Please discuss how the narrowness of the test flume (roughly 4 inches at its minimum) affected the level of turbulence generated in the test flume versus the plant condition that typically has much wider flow channels.

Response to RAI 11:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. Subsequently, on August 10, 2009, the information in response to this request was discussed with the NRC Staff [Ref. 1.N].

See revised Section 3.e.1.2 for a description of the sources of drainage that enter the pool including those near the strainer. Section 3.j.3 describes the modifications made to minimize the turbulence near the strainers caused by drainage. See Section 3.f.3.2 for the additional information requested regarding the test flume.

A CFD comparison of the debris transport model to the test flume was performed. NRC in the August 10, 2009 meeting. This comparison was discussed with the NRC Staff in a July 23, 2009 conference call.

12. Please identify the phenomenon or phenomena responsible for the removal of 20 percent of the latent debris that was assumed not to reach the recirculation sump strainers. If debris settling based on Stokes' Law was credited, please provide justification. If more than 15 percent of the latent debris was assumed to be held up in inactive pool volumes, please provide justification.

<u>Response to RAI 12:</u>

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.e.3 and below.

No settling of latent debris in the recirculation pool was credited. Although a much larger fraction of debris would likely be washed to the inactive reactor cavity during pool fill, the transport fraction was conservatively limited to 15% in accordance with the SE [Ref. 4.A, Volume 2].

13. Based on page 63 of the November 26, 2008, supplemental response, it appears that the recent testing using the revised PCI protocol was performed with a static water depth of 4.17 ft. Please describe any testing performed with the revised PCI test protocol in 2008 or later that includes modeling of the transient containment water level or small break LOCA water level conditions.

Response to RAI 13:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.f.1, 3.f.3.2 and below.

The transient flood up for LOCA was demonstrated during prototype testing [Ref. 8.D.1 and 8.D.2] and was witnessed by the NRC [Ref. 1.M]. The maximum flow rate during the transient is less than 40% of design. The debris introduction at the beginning of the transient test was conservative and the flood up rate was the minimum resulting in a maximum challenge to the strainer. The maximum transient (25 minutes) was less than the minimum pool turnover time during the transient (30.5 min). The maximum head loss during the transient was 0.005 ft. Transport analyses confirm that transport during full recirculation bounds the transient phase. Testing with the revised protocol confirmed that debris accumulation and head loss took significant time to develop. Therefore, a second transient flood up test was not required.

14. On page 68 of the November 26, 2008, supplemental response, in a number of areas, statements are made to the effect that, because certain types of debris were shown not to transport at fluid velocities of [x] feet per second (ft/s), they were removed from testing. In all of the cases, the values of x stated are less than or of the same order as the flume velocities listed on page 63 of the same supplemental response. Please justify these statements. For example, given that the flume velocities are in the range of 0.41– 0.62 ft/s, it does not logically follow that debris shown not to transport at 0.1 or 0.2 ft/s should be excluded from the testing. The NRC staff expects that transport testing be conducted at velocity and turbulence conditions that are prototypical or conservative with respect to the plant condition.

Response to RAI 14:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.f.3.2.

15. Please provide a basis to add the majority of the latent fiber to Test 4, Design Basis Debris Loaded Strainer Head Loss Test, prior to the starting of the test pump. It appeared

that approximately two-thirds of the latent fiber was added in this manner with no flow in the flume. This step was not a part of the version of the revised PCI protocol that had been reviewed by the NRC staff. Such a quiescent condition does not appear consistent with the expected flow conditions in the containment pool during washdown and pool-fill, as evidenced by the volunteer plant study in Appendix III to the SE. The licensee stated that Test 4 was the only test for which this practice was followed; however, it was the design-basis strainer head loss test, so it is the only test that is significant for the strainer head loss measurement.

Response to RAI 15:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.f.3.3 and below.

The basis for this addition prior to the recirculation pump was to address the NRC's concern during the Wolf Creek / Callaway testing that latent fibrous debris could be near the sump strainers after pool-fill at the initiation of sump recirculation. Since this issue was brought up by the NRC as a concern, it was included in the Comanche Peak strainer testing. Therefore, in the Comanche Peak design basis test, a small quantity of the fine fibrous debris (0.5 lbm) was placed in the flume prior to actuation of the.recirculation pump.

For test 4, 0.5 lbm of the 0.701 lbm of latent fiber was introduced to the surface approximately 5 minutes before starting the pumps. Flow was recirculated approximately 30 minutes before additional debris was introduced. The transport velocity and turbulence in front of the debris interceptor picked up any fines that had settled. Settling of the latent fibers is prototypical as described in Section 3.e.1.1.

Test 2 (fiber only) strainer head loss data at 367 gpm was about 0.082 ft. at 117.9 °F before fine fibers were introduced. Five (5) minutes later the head loss was 0.115 ft. Review of the Test 4 data: Flow started at 11:00 am. Recoding head loss with flow started at Ref.11:03 am – 0.110 ft. At 11:06 am it was 0.111 ft. at 111 °F. By comparison to test 2, this strongly indicates most of the latent fiber had reached the strainer.

In July 2009, a separate fiber transport test was performed in a small flume. The transport portion of the head loss flume was replicated so that the behavior of fiberglass could be documented. This test showed the latent fibers that had settled were picked up and transported when the test flow was initiated. A video of the test was provided to the NRC [Ref. 2.S].

Therefore, it was concluded that impact on the test results by the introduction of latent fibers before pump start was insignificant.

16. Please justify including a sharp turn directly before the strainer in the head loss flume. This sharp turn may have assisted in the removal of debris and in the creation of a nonuniform bed on the test strainer. Please explain how this sharp change in flow direction is prototypical of the plant. Please explain how the debris diverter was modeled in the computational fluid dynamics simulations. The computational fluid dynamics simulations for the plant condition appear to show velocities significantly higher than 0.1 ft/s near a good part of the strainer surface. Furthermore, the computational fluid dynamics simulations also show that flow does approach the strainers directly over a significant part of their surface area, and that such a sharp change in flow direction directly in front of the strainer is not representative of the velocity vectors approaching the plant strainers.

<u>Response to RAI 16:</u>

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.e.1.2 and 3.f.3.2.

17. From the pictures of the new strainer installation in Appendix A to the November 26, 2008, supplemental response, it is not clear to the NRC staff where the debris interceptor credited in the head loss testing is located. Please state where the interceptor is located, identify whether it surrounds the entire strainer for both sumps, and provide photographs showing its location.

<u>Response to RAI 7:</u>

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See Revised Section 3.j.2 for the requested information.

18. Page 63 of the November 26, 2008, supplemental response provides a table of the velocities in the PCI test flume for the recent testing with the revised protocol, which indicates that the velocities in the test flume ranged from approximately 0.47 to 0.62 ft/s. However, page 7 of Appendix D to that response indicates that the maximum flume velocity was 0.5 ft/s (for clean strainer testing). Please explain this apparent discrepancy.

Response to RAI 18:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The text provided with the picture in Attachment D was an approximate nominal flow rate rather than the maximum. It has been corrected to indicate the maximum of 0.62 fps.

19. Floating debris (e.g., duct tape, bumper sticker material, and radiation tape) was excluded from the strainer head loss evaluation. Please address the following points concerning debris floatation:

a. Please provide information that justifies that debris that floats cannot transport to the strainer and occlude portions of the strainer area, considering that recirculation begins prior to the strainer being fully submerged. In some cases, the strainer has a large portion of its surface area above the flood level when the switchover to recirculation occurs. The supplemental response indicates that a transient large-break LOCA case was tested and verified to be acceptable; however, this test was performed to an earlier PCI protocol that the NRC staff considers non-prototypical. Furthermore, the test case did not examine long term operation of the strainers at reduced water levels representative of a small break LOCA.

b. The November 26, 2008, supplemental response states on page 42 that Alion Science & Technology performed testing of miscellaneous debris including tape, labels, and coatings. Please describe whether the potential for transport via floatation was examined in this series of tests.

Response to RAI 19:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See Revised Section 3.f.3.3 for the requested information.

20. Please address the following items concerning the addition of large pieces of fibrous debris to the head loss tests, particularly the design-basis head loss test (Test 4).

    a. Considering the presence of a 1-foot high interceptor, it appears unlikely that large debris pieces would have been capable of climbing over such an obstruction. Examination of the transported debris in sensitivity tests or earlier head loss tests that used large pieces would have allowed this hypothesis to be verified. Please state the basis for considering the transport of large pieces to be credible under the test flume conditions with the 1-foot debris interceptor and identify whether transport of large pieces was observed during head loss tests or transport sensitivity tests that were performed with the interceptor installed.

    b. In addition, it is unclear to the NRC staff how transport of large pieces could have been prototypically modeled in a flume having a width of the same order as typical large debris pieces. Please identify the distribution of sizes of the large pieces of debris added to the test flume and state whether any of the pieces became stuck in the narrow test flume due to non-prototypical interactions with the flume walls.

    c. In light of the observations above, please identify whether the addition of large debris pieces under such conditions resulted in a non-prototypical means of filtering out chemical precipitate subsequently added to the head loss test.

Response to RAI 20:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.f.3.3 and below.

Large LDFG was included in the test in accordance with the test protocol which was reviewed by, and discussed with, the NRC Staff. Debris was to be included where the debris transport analysis did not preclude transport to the strainer. The flume testing was not only performed to demonstrate strainer performance. The debris interceptor performance was also a test objective. The purpose of such testing is to show that a ramp does not form over the debris interceptor.

Large LDFG was prepared as described in Section 3.f.3.1. Figures 3.f-3 and 3.f-4 show pictures of the prepared large Nukon fiberglass. During testing, the pieces of large fibrous debris was observed to be sufficiently smaller than the flume width such that they could not become stuck. Note that "intact blankets" were also prepared the same as large Fiberglass. The conservative debris preparation resulted in both large and intact fiberglass pieces closer to smalls than to large fiberglass pieces as defined.

Since the "large pieces" were too small to become stuck, settling in the flume was prototypical. Therefore, any interaction with chemical precipitates would also be prototypical.

21. Please state whether the sump is vented to the containment above the minimum water level at which the strainer becomes submerged. If it is, please evaluate failure modes such a condition potentially introduces.

<u>Response to RAI 21:</u>

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.j.2 for the requested information.

22. The vortexing, air ingestion, and void fraction evaluations were not performed at the minimum containment flood level. The potential for a partially submerged strainer was not fully addressed. Please provide information that shows that the strainer will perform adequately with respect to vortexing, air ingestion, and void fraction at the most limiting submergence value and flow rates for the strainer. One potential issue is that the licensee assumed that containment sprays will actuate in a maximum of 25 minutes and flood the strainer in a short period of time. For a small-break LOCA, spray actuation need not occur immediately or at all, such that the strainer could be operating for a significant period of time at a reduced water level (with only ECCS flow for small-break LOCA conditions). Analysis has not been presented to demonstrate acceptable strainer performance under this condition. The partially submerged strainer issue is particularly critical because the strainer core tube is only submerged by 2.2 inches at ECCS switchover for a small-break LOCA. In other words, if the head loss from the outer perforated plate and any accumulated debris on the outer surface of the strainer exceeds 2.2 inches, the core tube would be uncovered, which could adversely and significantly impact the performance of the strainer. The situation is complicated further by the fact

that, even if the head loss across the perforated plates is low when a uniform flow calculation is used, if the perforated plate clean strainer head loss plus debris head loss is not small compared to about 2 inches, then reduced flow is going to reach the pump suctions from the plates that are farthest away (i.e., the PCI strainer will have increasingly non-uniform flow as this value is approached and potentially exceeded), since only a 2.2-inch margin in driving head is available to move water through the strainer surface prior to core tube uncovery.

Also, since the core tube slots are likely designed for full flow, having less than the design flow will lead to greater flow at the near modules. Thus, more flow (and debris) will concentrate on the nearest module to the suction, and the head loss through these nearby disks will increase. Assuming uniform debris distribution in this case may not be conservative. In addition, vortexing could occur inside the strainer disks above the core tube slots. Please explain whether core tube performance testing has been done with only 2.2 inches of submergence to verify no vortexing or flashing at the slots. Furthermore, based on page 15 of 20 in Attachment E, there appear to be sources of drainage nearby the strainers, which could potentially disturb the water surface near the strainers and core tube slots and result in air entrainment. Please provide the assumptions used in the air ingestion and void fraction calculations, and infomation that justifies the assumptions. Alternately, for the air ingestion issues, please provide test data, taken under conservative conditions, that show that air ingestion will not occur for the strainer as installed in the plant. Note that, with the strainer only partially submerged, air entering the core tube may not be identified visually so that alternate means of identifying air entrainment may be required. The response to this item should also consider that any debris that is considered to transport to the strainer under partially submerged conditions would accumulate on the reduced strainer area.

Response to RAI 22:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.e.3 for a discussion of the small break LOCA debris transport analysis. See revised Section 3.f.1 for a discussion of SBLOCA flood levels and the switchover transient. See revised Section 3.g.1 for a discussion of the system responses to SBLOCA.

23. Please provide the margin to flashing considering that a more limiting condition may occur at the minimum water level, with the core tube covered only by a small amount of water. The flashing evaluation may have to be performed for several conditions in order to provide assurance that the limiting condition has been identified. With only a small amount of water covering the core tube, it is possible that the clean strainer head loss alone could result in flashing of the fluid within the strainer if some overpressure is not credited in the evaluation.

Response to RAI 23:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The additional information requested is provided in Section 3.f.4.3.

24. It is not clear that the main steam line break (MSLB) case was bounded by the testing that was conducted with a procedure that the NRC staff considers to be acceptable in principle. The reference for the testing was dated August 2006, which is prior to the time at which the NRC staff largely accepted a PCI/AREVA test methodology. In fact, trip reports from NRC staff observations of the early testing identify several non-conservative aspects of the testing. The more recent testing, conducted with the upgraded test procedure, did not appear to bound the debris loading for the MSLB (e.g., fibrous and Min-K debris). Please provide information that justifies that the testing used to bound the MSLB case was conducted in a manner that would result in prototypical or conservative results and that it was conducted with debris representative of that break.

Response to RAI 24:
Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The response to RAI 24 was provided in the attachment to TXX-09114 [Ref. 2.R]. See Section 3.e.4 and the response to RAI 37 for the revisions to incorporate this additional information.

25. The NRC staff could not determine whether some of the fine fibrous debris was blended into non-prototypical debris. The test photos in attachment D (pages 10 and 29) to the November 26, 2008, supplemental response appear to show clumps of debris that are larger and more agglomerated than would be expected of prototypical fine debris. The debris could have been blended excessively or into a form that is not prototypical of

debris created by a steam jet. Please provide information that shows that the fibrous debris had prototypical characteristics when added to the test tank and that the debris was not agglomerated when added. In general, the NRC staff considers class 1-3 fibers (reference Table 3-2 in NUREG/CR-6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," February 2003) to be acceptable as fine fibrous debris with the majority being class 2 or 3. In addition, information should be provided that justifies that excessive agglomeration of debris did not occur during the debris addition process.

Response to RAI 25:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.f.3.1 and below for the requested information.

PCI utilized the guidance provided in NEI 04-07 and the Staff's SE for NEI 04-07 for the initial preparation of the Large Flume Test Protocol. The subject Protocol was discussed face-to-face and in numerous telephone conversations with the Staff prior to the first Licensee test in early 2008. Based on comments from the Staff during the first Licensee test as well as 'lessons learned' from the subject test, the Large Flume Test Protocol was further revised to address both the Staff's comments and the 'lessons learned'.

The fiber classes 1 – 3 per NUREG/CR-6808, Table 3-2 are acceptable with regard to defining fine fiber. It should be noted that the subject NUREG/CR and Table are specifically associated with Section 3.1.2.1 Size Classification of Fibrous Debris of the subject NUREG/CR. The subject Section is based on blast testing experiments of fibrous debris. In other words, the debris sizing classification in Table 3-2 is based on dry simulated post-LOCA destroyed fibrous debris.

Prior to the initiation of any Licensee testing and the completion of the Large Flume Test Protocol, PCI presented various samples of processed fibrous debris to the Staff in late 2007 during a GSI-191 public meeting. The samples were presented to the Staff in order to solicit comments or recommendations regarding the processing and size classification of the processed fibrous debris with regard to the proposed Large Flume Test Protocol. The subject samples consisted of the three (3) classifications of fibrous debris: latent, fines/smalls, and larges as defined in NEI 04-07 and the subsequent Staff SE.

The Staff indicated that the subject samples were representative of what they expected for each of the three (3) subject classifications of dry fibrous debris. It should be noted that PCI and the Licensees utilize a more conservative definition of fines/smalls than that of the guidance documents (i.e., NEI 04-07 and the Staff's SE for NEI 04-07). PCI utilizes a 1" x 4" grating in lieu of the recommended 4" x 4" grating to separate fines/smalls from larges. Therefore, the PCI definition of fines/smalls results in significantly smaller-sized fibrous debris than, if the guidance recommendation were followed. Again, it should be noted that neither NEI 04-07 or the Staff's SE, specifically addressed, provided guidance, or discussed the size classification of fines/smalls and larges.

During the last major public GSI-191 meeting held by the Staff on October 24, 2007, the issue of fibrous debris 'fines' was specifically discussed and questions were raised by the Licensees and NEI. In this meeting, the Staff agreed and stated in the meeting that 'fines' were not single fibers, but could be 'clumps' or 'bunches' of fibers.

In conclusion, all of the fibrous debris (i.e., latent, fines/smalls, and larges) for all of the Licensees has been processed, prepared, and introduced to the test flume in accordance with the PCI 'white paper' Sure-Flow Suction Strainer - Testing Debris Preparation & Surrogates, the PCI/AREVA/Alden Large Flume Test Protocol, and most importantly by the same Alden personnel (in most cases). Observations and comments by the Staff and lessons learned by PCI/AREVA/Alden during the initial Large Flume Test were incorporated into all subsequent tests. There has been a significant level of consistency in the processing, preparation, and introduction of latent, fines/smalls, and large fibrous debris into the Large Test Flume. It should be further noted that samples of processed fibrous debris (dry material) as latent, fines/smalls, and larges were provided to the Staff and the determination was made that the samples were representative of what the Staff had expected when diluted properly. The concern when PCI first implemented the introduction of fines was that we were not diluting sufficiently. Since that very first test; PCI increased the dilution of fibers prior to and during introduction to relieve the NRC concern. To our knowledge, this practice was acceptable to the NRC witnesses since that time.

In conclusion, the preparation and introduction of fine fibrous debris did not promote the agglomeration of the debris and did not inhibit the transport of same other than what would have naturally occurred in an open, free flowing water stream such as the post-LOCA containment following initiation of ECCS recirculation.

26. One of the test photographs shows 1.66 pounds mass (lbm) of fine fibrous debris. This would correlate to 56.8 lbm of debris in the plant. It was unclear what fibrous debris this represented. It appears that the fine debris should have been 30 lbm of latent fiber (although one place shows 24 lbm) and 33 lbm of fine low density fiberglass (LDFG) debris. The total fine fiber would then be 63 lbm. Please clarify the amount of fibrous fines predicted to reach the strainer and verify that the test amount was scaled correctly.

Response to RAI 26:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L].

The 1.66 lbm of fine fiber debris shown on the test photograph in Attachment D was Nukon fines comprised of 0.954 lbm for LDFG and 0.701 lbm for latent debris fibers.

The scaling factor for the testing was 2.9225%.

LDFG Fines - (13.6 ft^3 x 2.4 lbm/ft^3) 32.64 lbm scaled to 0.954 lb
Latent Fiber - (10 ft^3 x 2.4 lbm/ft^3) 24 lbm scaled to 0.701 lb

Based on the table presented above, the test amounts were scaled correctly.

The test 4 photograph in Attachment D has been clarified.

27. NRC staff review of the November 26, 2008, supplemental response identified that the debris addition practices and sequence used during the testing may not have been conservative. Please provide information that justifies that the debris addition sequence and practices did not result in non-conservative debris transport to the strainer during testing. Examples of potential non-conservative practices include adding more easily transportable debris after adding less transportable debris. It appears that the addition of 6 mil paint and lead blanket cover fines in the second batch of debris is contrary to adding the most transportable debris first. From the supplemental response, it was difficult to determine how the debris was actually added. For example, was each debris type added separately or were the debris added as one addition? If added separately, please provide the order of addition.

Response to RAI 27:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. As documented in the Comanche Peak Test Plan (Ref. 8.D.6), the debris types were introduced into the test flume separately (see revised Section 3.f.3.3) and that the 6 mil paint chips were added prior to the lead blanket covers. As shown in the Picture on Page 9 of Attachment D, the lead blanket covers (fines) had a size distribution similar to "small" low density fiberglass (or NUKON). Therefore, the lead blanket covers were added after the 6 mil paint chips (powder) since the lead blanket covers were less transportable (fine fibers).

28. It was unclear that the extrapolation of the test data to the strainer mission time was conservative. Please provide infomation that justifies that the exponential curve fit results in a conservative estimation of head loss at the end of the mission time. Please include adequate data so that the NRC staff can verify the results of the extrapolation. Please provide information on how the linearly extrapolated value is used in any analyses or provide the reason that it was included in the supplemental response.

Response to RAI 28:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The linear extrapolation was performed for information only. It was not used in any subsequent analysis. See revised Section 3.f.3.3 and pages 45 and 46 of Attachment D which show the extrapolations superimposed on the test data. The curve fit method is conservative because the form of the equation used to fit the data does not allow a decrease of head loss in time and determines an asymptotic limit for head loss.

29. It appeared that the extrapolation of test results to different temperatures assumed that the flow through the debris bed was fully laminar. However, the supplemental response stated that there was clean strainer area at the end of the test. With clean strainer area, the flow through the strainer may not have been fully laminar. If this is the case, a straight viscosity correction should not be applied for temperature correction. Please provide the methodology and initial conditions used to calculate the debris head loss at higher temperature conditions. Also, provide information that justifies the use of a straight viscosity correction for the debris head loss if one was used.

Response to RAI 29:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. A flow sweep was performed at the end of the head loss testing to confirm laminar flow through the debris bed. See revised Section 3.f.3.3 and page 44 of Attachment D.

30. Please describe the testing and analysis performed on the declassified coatings in order to re-classify them as acceptable. Also, please describe maintenance activities on the declassified coatings in the period before being upgraded to acceptable.

Response to RAI 30:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.h.2 for the requested information.

31. The discussion of coatings in the November 26,2008, supplemental response is unclear in that on page 93, the licensee mentions that steel coatings within 100 of a break are assumed to be unqualified for a design-basis accident, and that 10-micron particles were assumed for such debris. However, in the bounding debris load tables for the LOCA and MSLB, there are no entries for unqualified coatings within a lOI, only for various unqualified coatings outside the lOI, while the only entries for lOI coatings are for acceptable coatings. Please state what quantity of unqualified coatings is destroyed in the lOI, and how they were handled in the bounding debris loading.

Response to RAI 31:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.h.2 for the requested information.

32. Please provide the hole size for the strainer that is installed over the 4-inch drain in the upender area that is described on pages 124-125 in the November 26, 2008, supplemental response. Please identify the potential debris loading that could reach this strainer, state whether the strainer can become plugged or partially plugged by debris, and provide a basis that blockage will not occur, if this flow path is necessary to satisfy assumptions in the analysis. Please identify what hold-up assumptions are made in the upender area in

order to generate sufficient driving head to overcome the clean strainer head loss and any head loss due to a debris layer that could form on the strainer's surface. If any hold-up of water is analyzed to occur, then please address the effect of this hold-up on the minimum containment pool water level calculation.

Response to RAI 32:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.l.2 for the requested information.

33. The NRC staff considers in-vessel downstream effects to not be fully addressed at CPSES, Units 1 and 2, as well as at other PWRs. The CPSES submittal refers to draft WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final SE for WCAP-16793-NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for CPSES by showing that the licensee's plant conditions are bounded by the final WCAP-16793-NP and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating, without reference to WCAP-16793 or the staff SE, that in-vessel downstream effects have been addressed at CPSES. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793.

Response to RAI 33:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. See revised Section 3.n.3 for the current status.

34. Integrated chemical effects head loss testing was performed in the flume at Alden Labs. (Le., the PCI/AREVA methodology). The WCAP-16530, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," dated February 2006, methodology was used to estimate the chemical precipitate load. The licensee used refinements to the base model methodology (i.e., credits using WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model," dated May 2007) without specifying which refinements were used, how they were used, or the

overall reduction in calculated precipitate load based on using these refinements. Since the licensee had some margins in the amount of precipitate load that were tested (compared to the calculated load), the NRC staff is uncertain if these margins bounded the reduction in precipitate due to "refinements." Please address the use of these refinements.

Response to RAI 34:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. Refinements to the base model methodology were not made. There was no use of WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model" [Ref. 6.C]. See revised Section 3.f.3.1.

35. The flume tests were performed with chemical precipitates added after other nonchemical debris. Credit was taken for settling of debris, both non-chemical debris and chemical precipitates, in the flume approaching the strainer test section. These tests were performed at a maximum flume fluid temperature of 120 of. The total head loss in the integrated chemical effect head loss flume tests was acceptable. The licensee makes a statement on page 150 of 351,

> Because chemical precipitates were first observed at and below 140 of, the head loss was calculated in accordance with [NRC Regulatory Guide (RG) 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps (Safety Guide 1)," dated November 1970] and [RG 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," dated November 2003].

Please address what this means and how this statement factors into the chemical effects evaluation.

Response to RAI 35:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L].

The statement on page 150 of the November 2008 response read as follows: "*Because* *chemical precipitates were first observed at and below 140 F, the head loss was calculated at 120 F and is slightly higher than at 212 F. When compared to the contribution of the air partial pressure (Section 3.g.2), the increase in head loss at the lower temperature is insignificant."*

The calculation of total strainer head loss [Ref. 8.B.7] was performed at the lower temperature for comparison and for information only. No credit for solubility or the increased NPSH margin at the lower temperature were taken. See revised Sections 3.g.1 and 3.o.3.1.

36. The licensee's response notes that the CPSES also has a buffer license amendment but has not made any commitment concerning a buffer change. Please address whether or not such a change will be made, including schedule.

Response to RAI 36:

Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L].

The buffer amendment was proposed as a contingency in case excessive head loss was caused by chemical precipitates during strainer testing. The current Sodium Hydroxide [NaOH] buffer concentrations were used in the analysis and testing. There are no current plans to implement the buffer reduction. Also, see Section 3.o.2.

37. The November 26, 2008, supplemental response indicates that plans do not exist to update the CPSES licensing basis for secondary pipe ruptures to include analysis of sump performance using mechanistic criteria consistent with Generic Letter (GL) 2004 02. Please address the following points regarding this decision:

a. Please identify the regulatory requirement(s) that resulted in crediting operation of the containment spray system in recirculation mode following a secondary line break inside containment in the CPSES licensing basis. Although, as the supplemental response noted, Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.46 was one of the applicable regulatory requirements identified in GL 2004-02, the GL was also based on a number of other regulatory requirements listed therein.

b. Although aspects of the licensee's secondary pipe rupture analysis are consistent with NEI 04-07, Section 3.3.4.1, the NRC staff stated in its SE for NEI 04-07 that the NEI 04-07 positions in this section were unacceptable. The NRC staffs SE discussion indicates that the same guidelines should be applied for secondary line breaks as for LOCAs. Please justify use of this section of NEI 04-07.

Response to RAI 37:

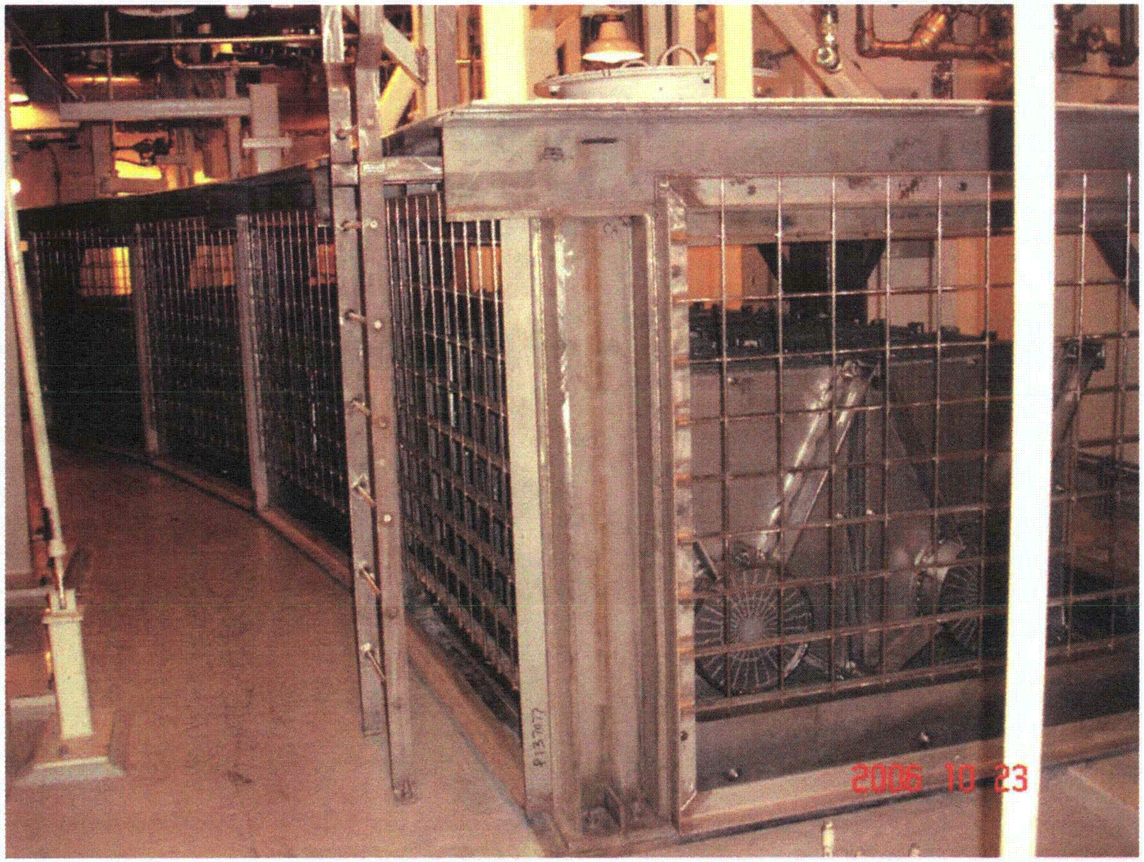
Information pertinent to this request was previously provided in the July 9, 2009 public meeting [Ref. 1.L]. The advance response to RAI 24 and RAI 37 was provided in the attachment to TXX-09114 [Ref. 2.R]. The technical information has been incorporated into this report in the following sections:

Section 2.1 General Description
Section 2.1.1 Modifications
Section 2.1.2 Qualification of the Strainer System
Section 3.a.2 Secondary Line Break Selection
Section 3.e.4 MSLB Debris Located at the Sump

As noted in each previous Luminant response to Generic letter 2004-02, the Current Licensing Basis for CPNPP, as well as plant-specific features, resulted in exceptions and/or interpretations being taken to the guidance given in RG 1.82 and NEI 04-07 as modified by the SER. The SER guidance for secondary line breaks is cited in the supplemental responses as one of those exceptions.

Although secondary line breaks are not included in the regulatory basis for Generic Letter 2004-02 and break locations in accordance with the current licensing basis cannot generate significant quantities of fibrous debris, CPNPP has evaluated the impact of arbitrary intermediate line breaks on emergency sump performance. Conservative analysis and testings show that ECCS design basis LOCA breaks bound secondary line breaks for emergency sump performance. Therefore, Luminant concludes that the intent of Generic Letter 2004-02 has been satisfied for secondary line breaks. A change to the current licensing basis to include arbitrary intermediate line breaks and perform the associated design basis strainer head loss testing for those breaks is not warranted. As noted in Section 3.p, the FSAR updates did not change the licensing basis for secondary line break locations or their effect on emergency sump performance.

Containment Emergency Sump Modifications



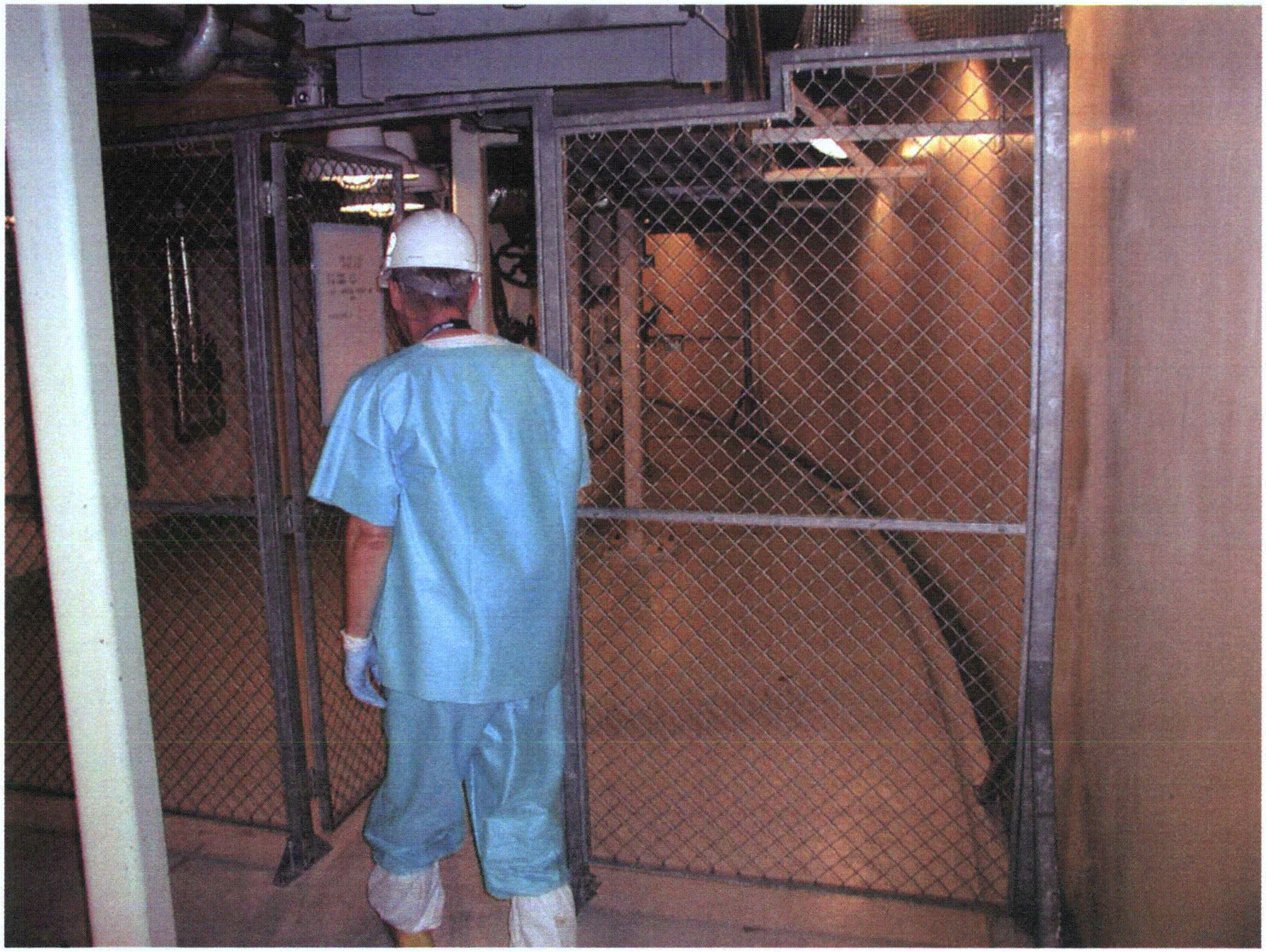
Incore
Instrumentation
Guide Tube Room

P-3.e.1-1 Door to Inactive Sump

P-3.e.1-2 Drain to Inactive Sump

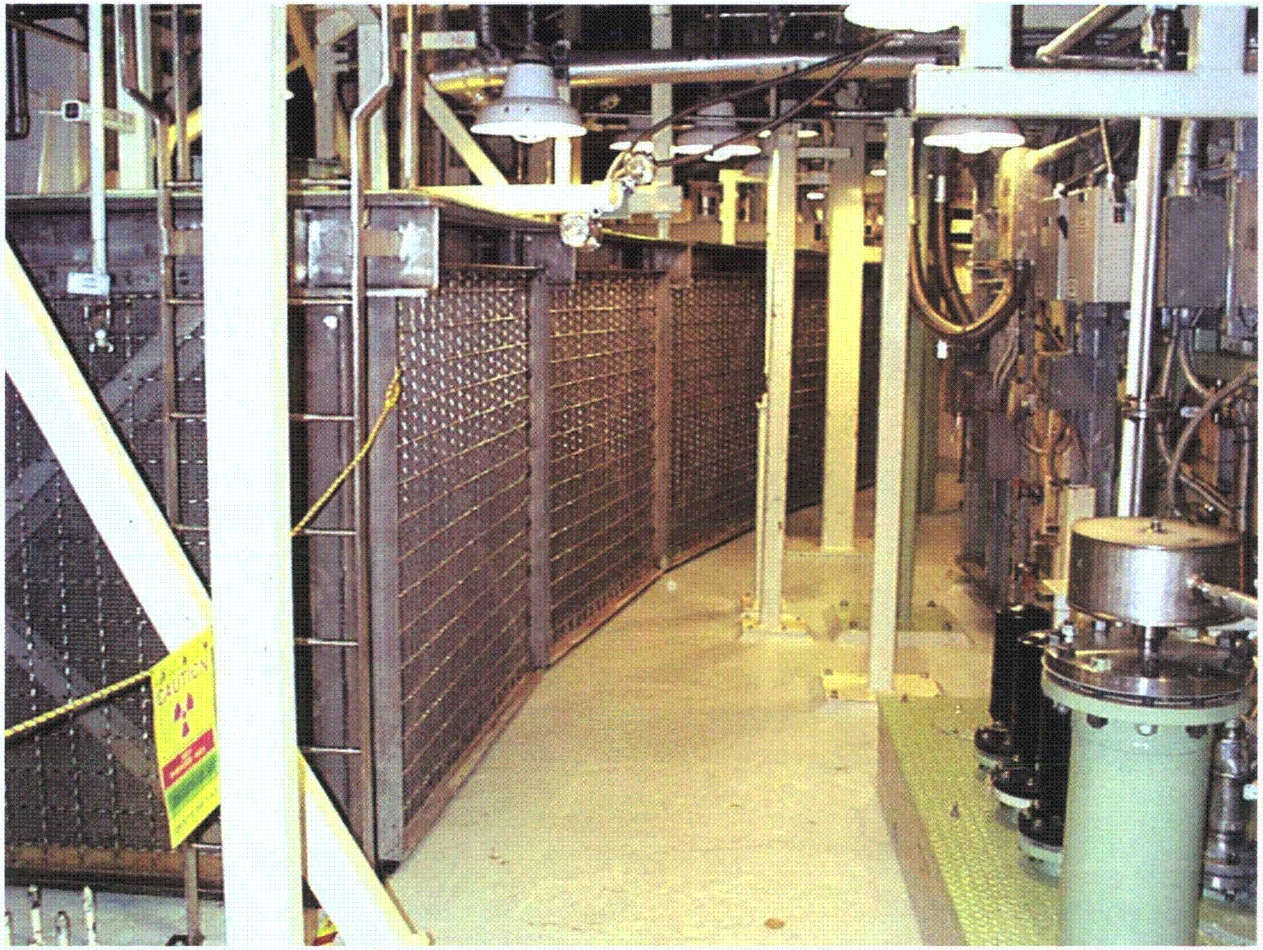
Modified

P-3.e.1-3 Drain to Inactive Sump

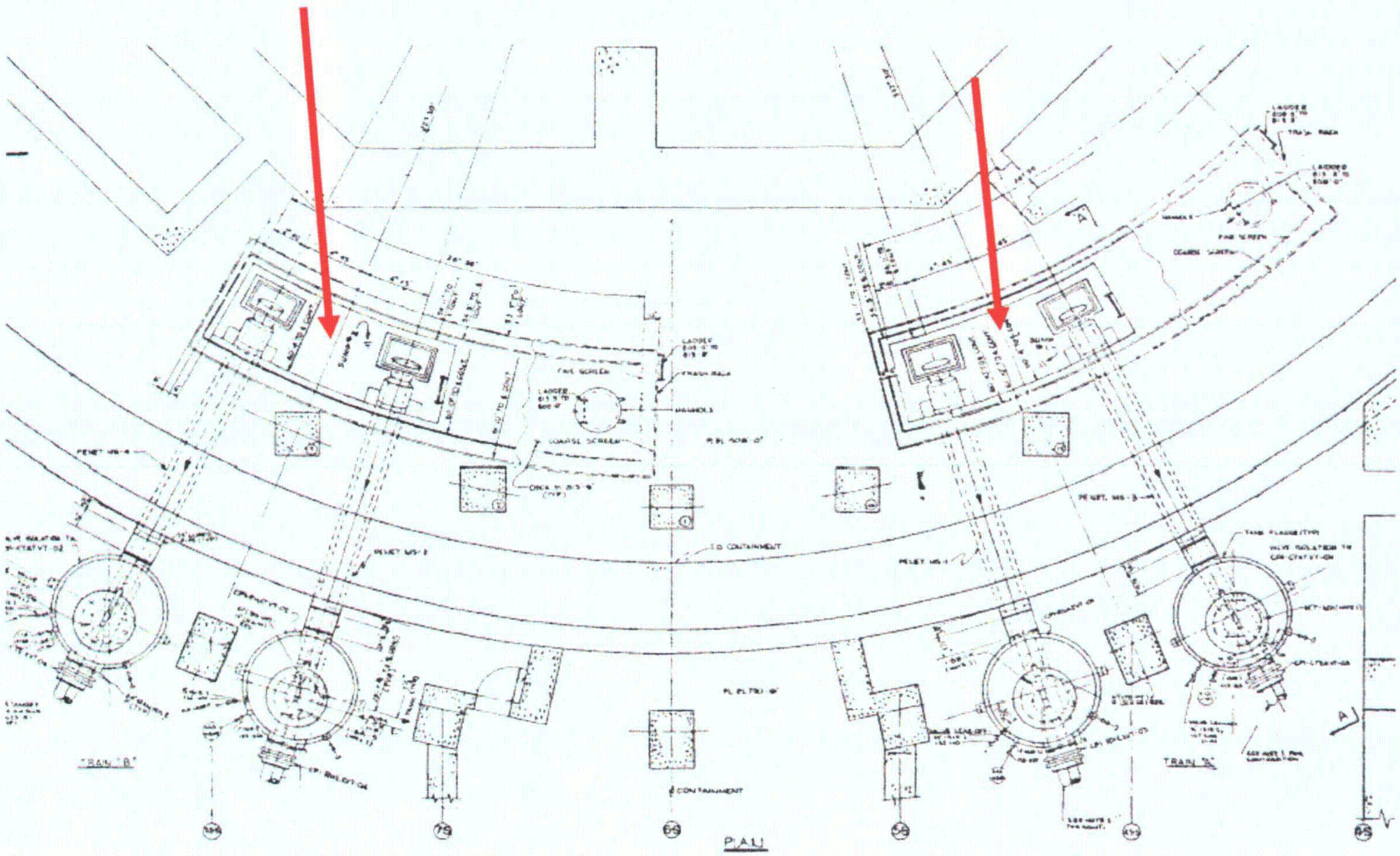


P-3.e.1-4 Wire Mesh Cage

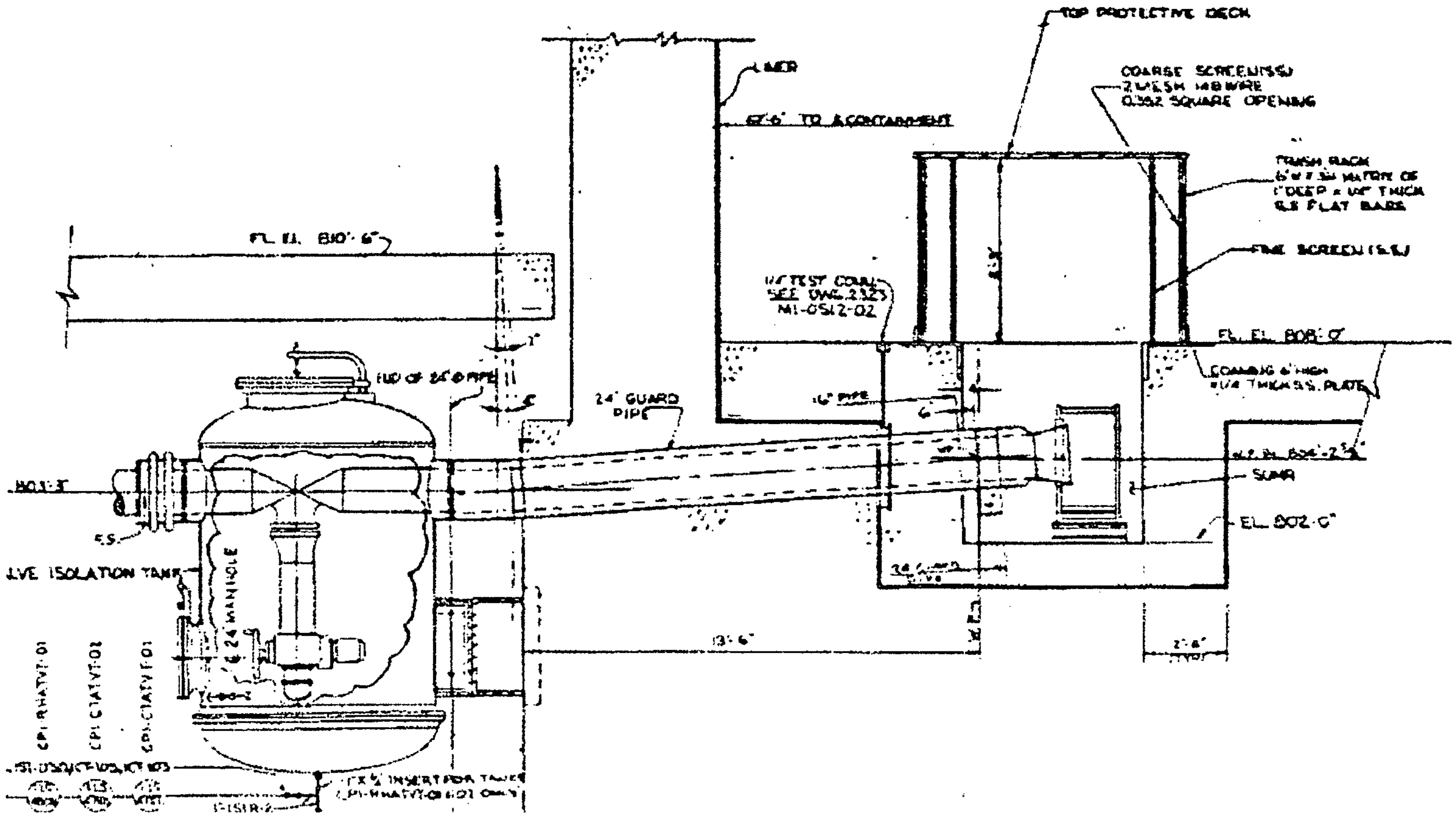
P-3.e.1-5 Unit 2 Tool Room



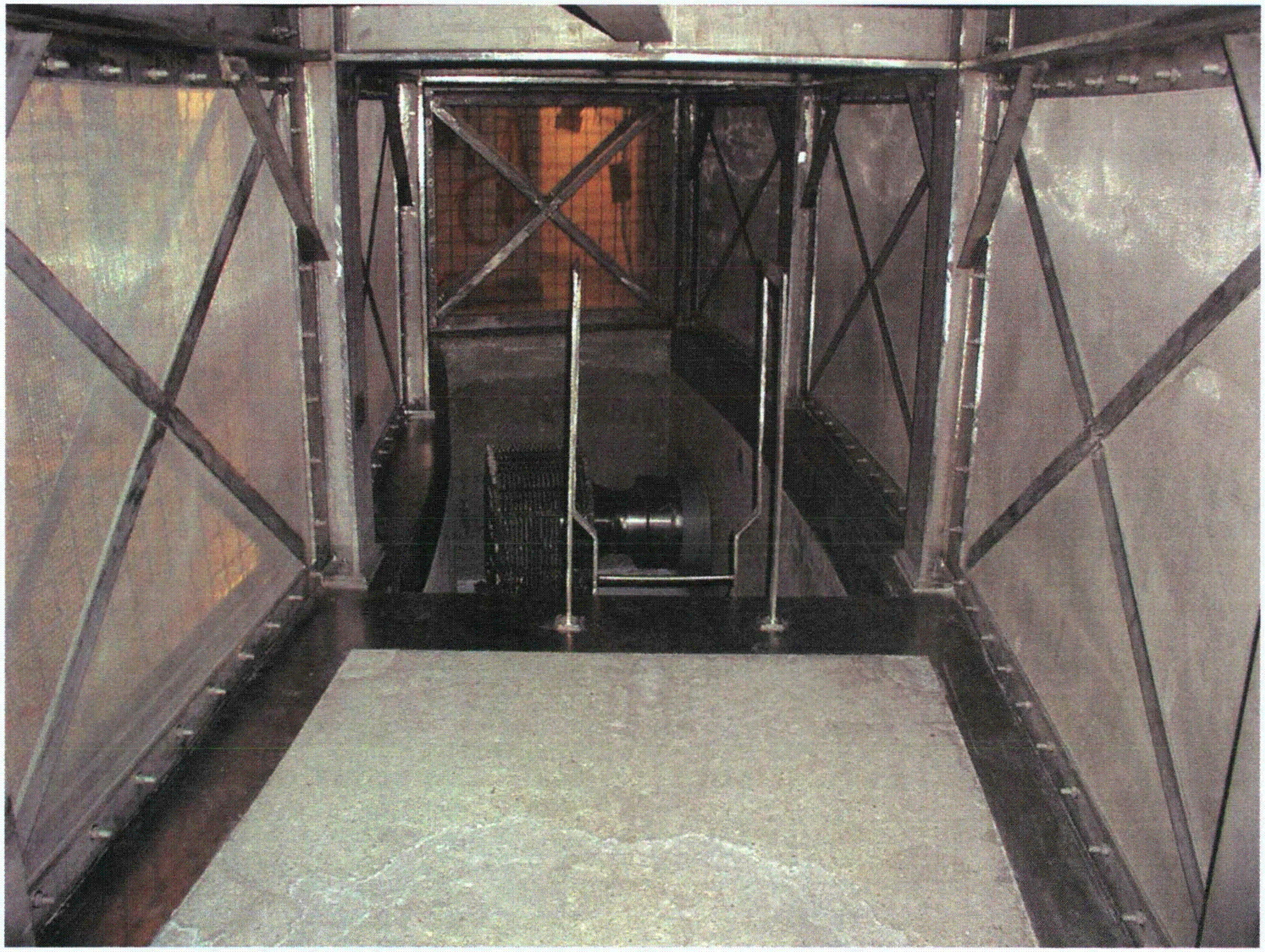
P-3.j.1-1 Original Sump Screens



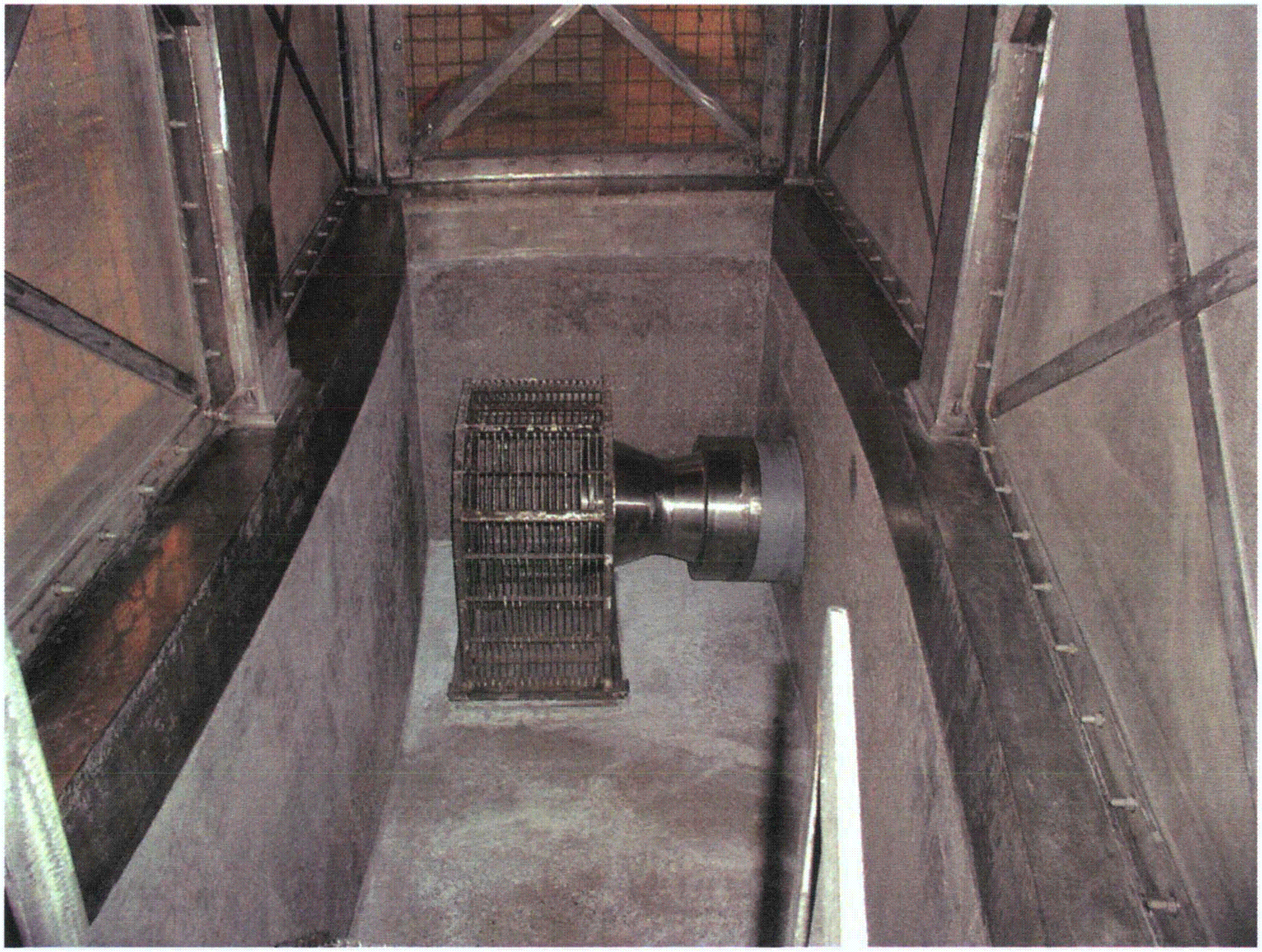
P-3.j.1-2 Emergency Sump Arrangement



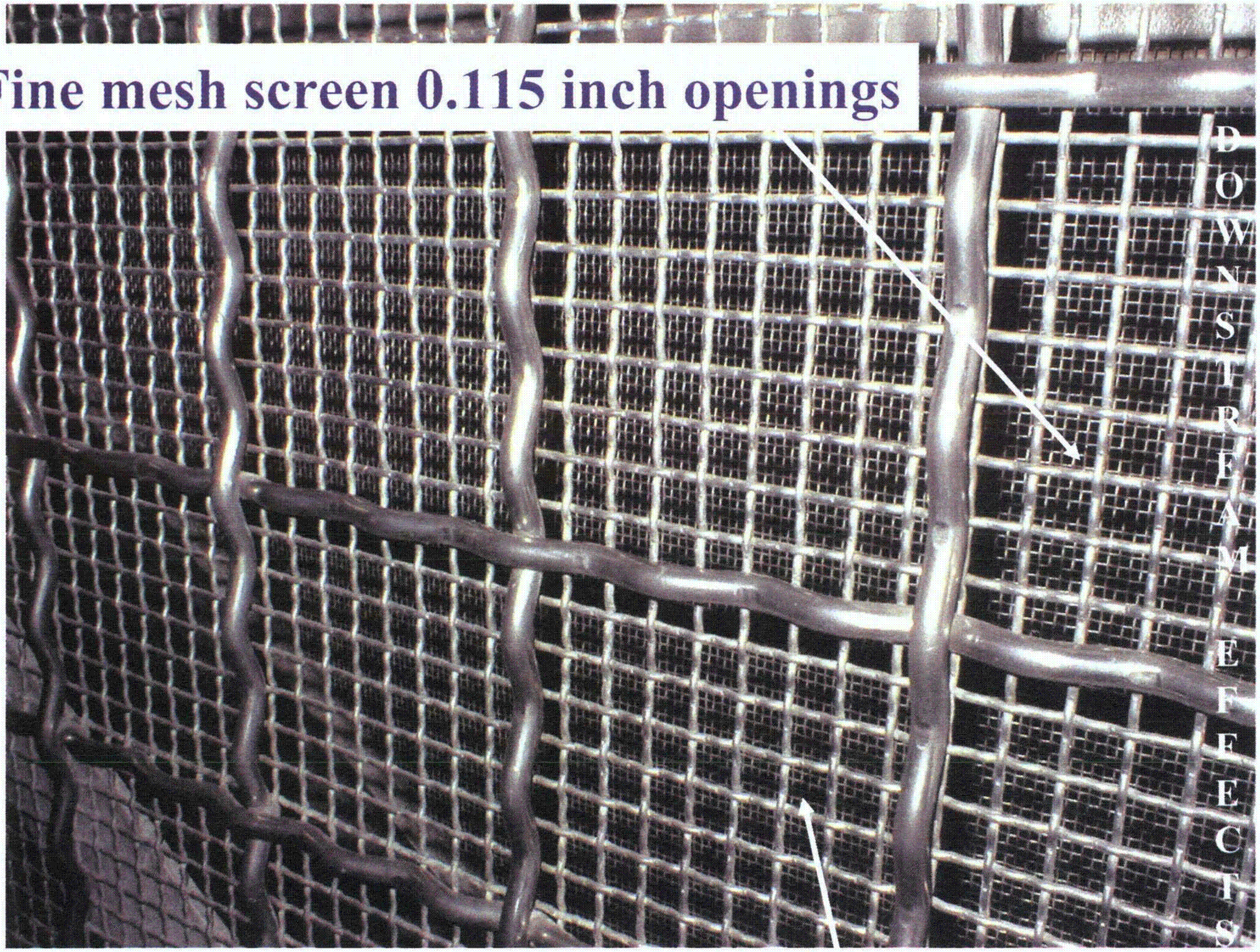
P-3.j.1-3 Emergency Sump Arrangement



P-3.j.1-4 Inside Sump Screens

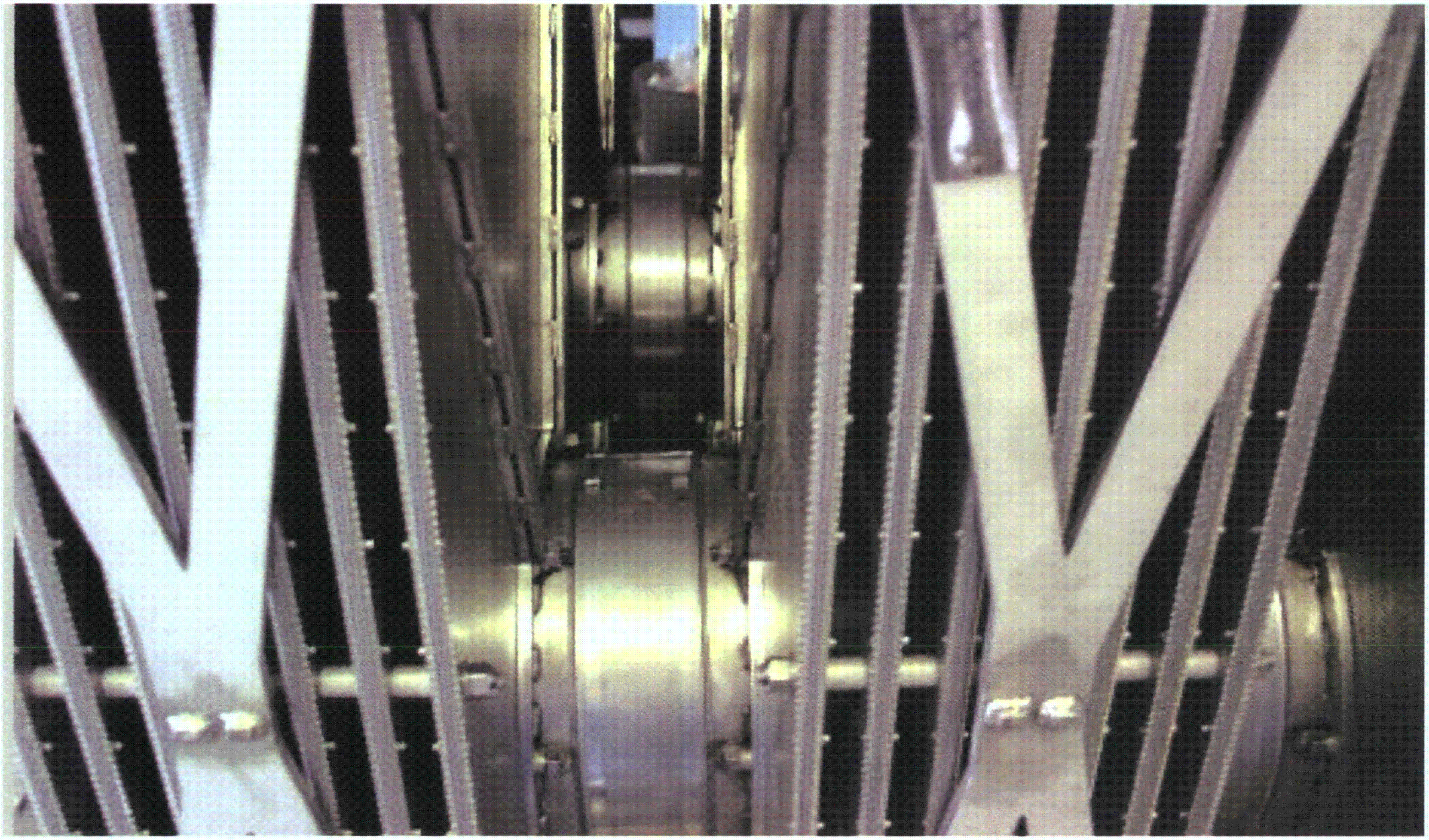


P-3.j.1-5 Vortex Suppressor

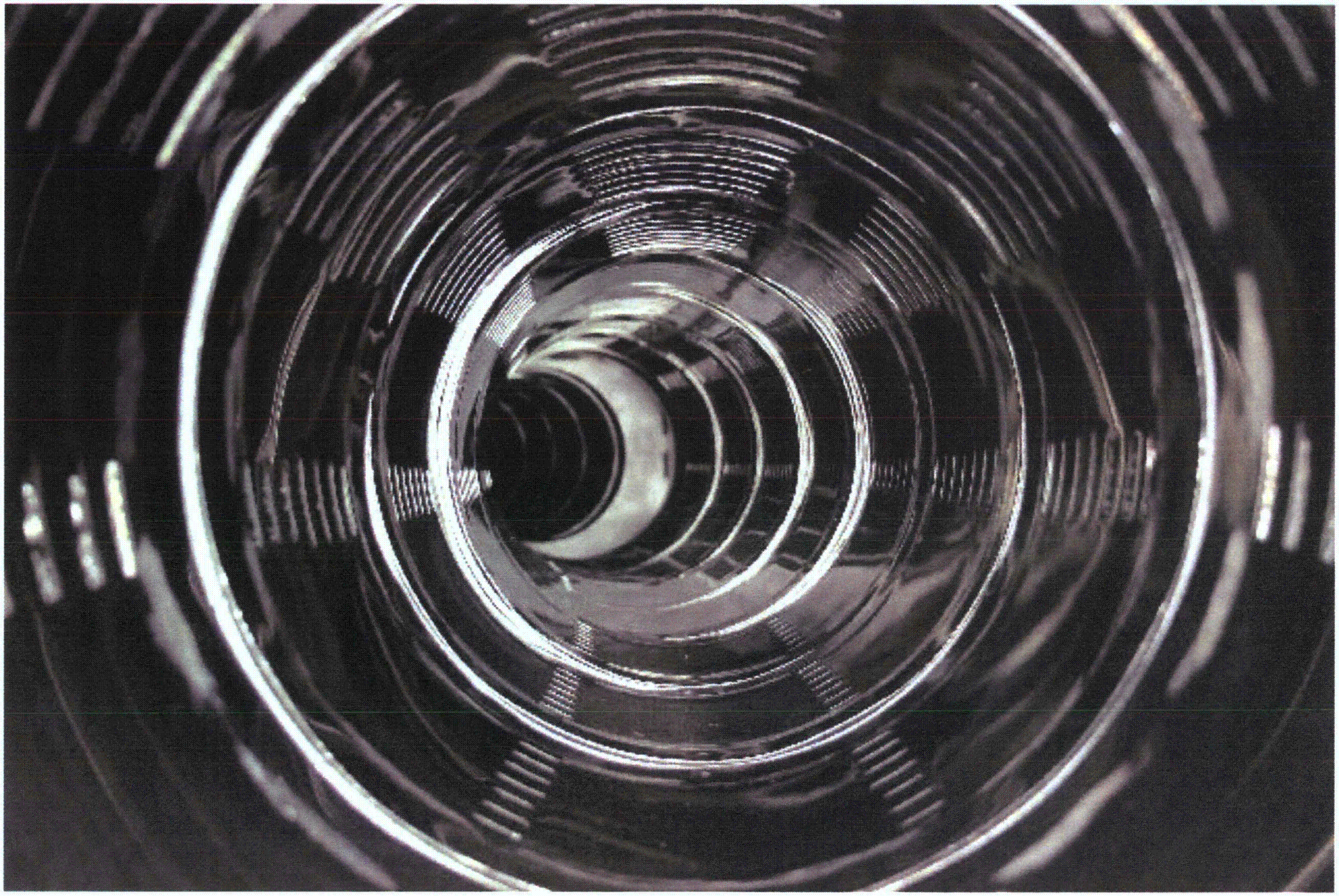


P-3.j.1-6 Original Sump Screens

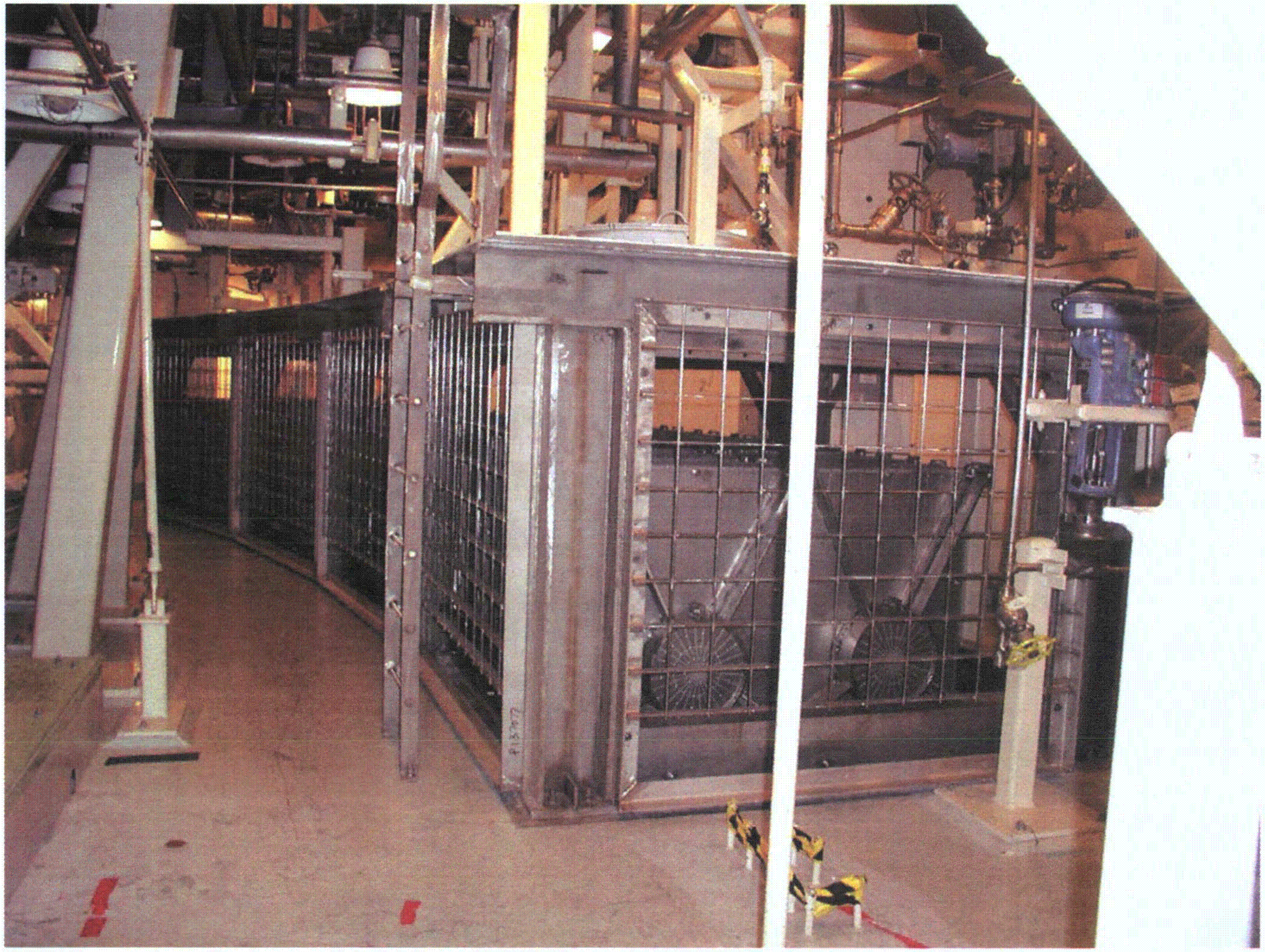
P-3.j.2-1 Shop Assembly



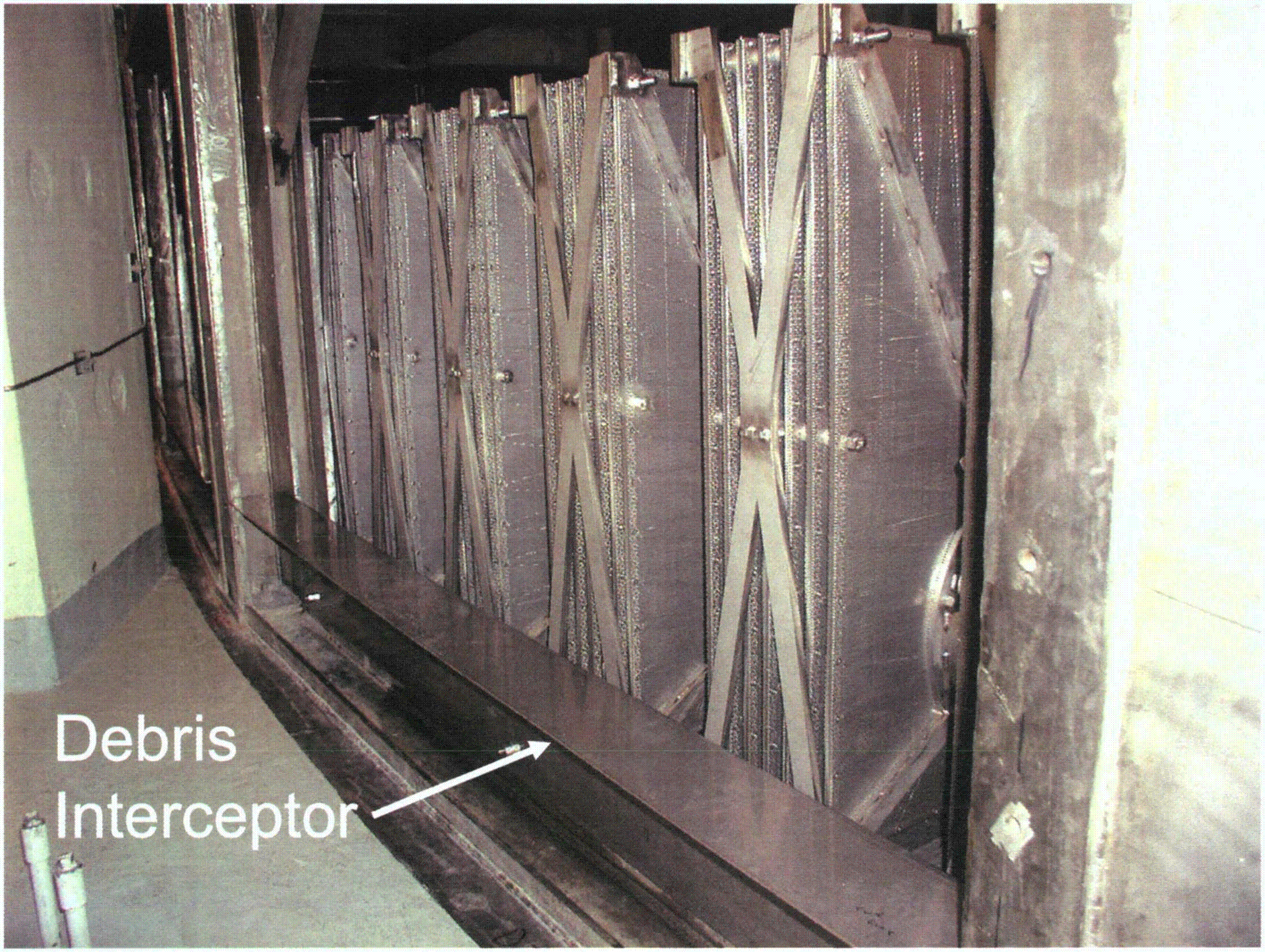
P-3.j.2-1a Shop Assembly



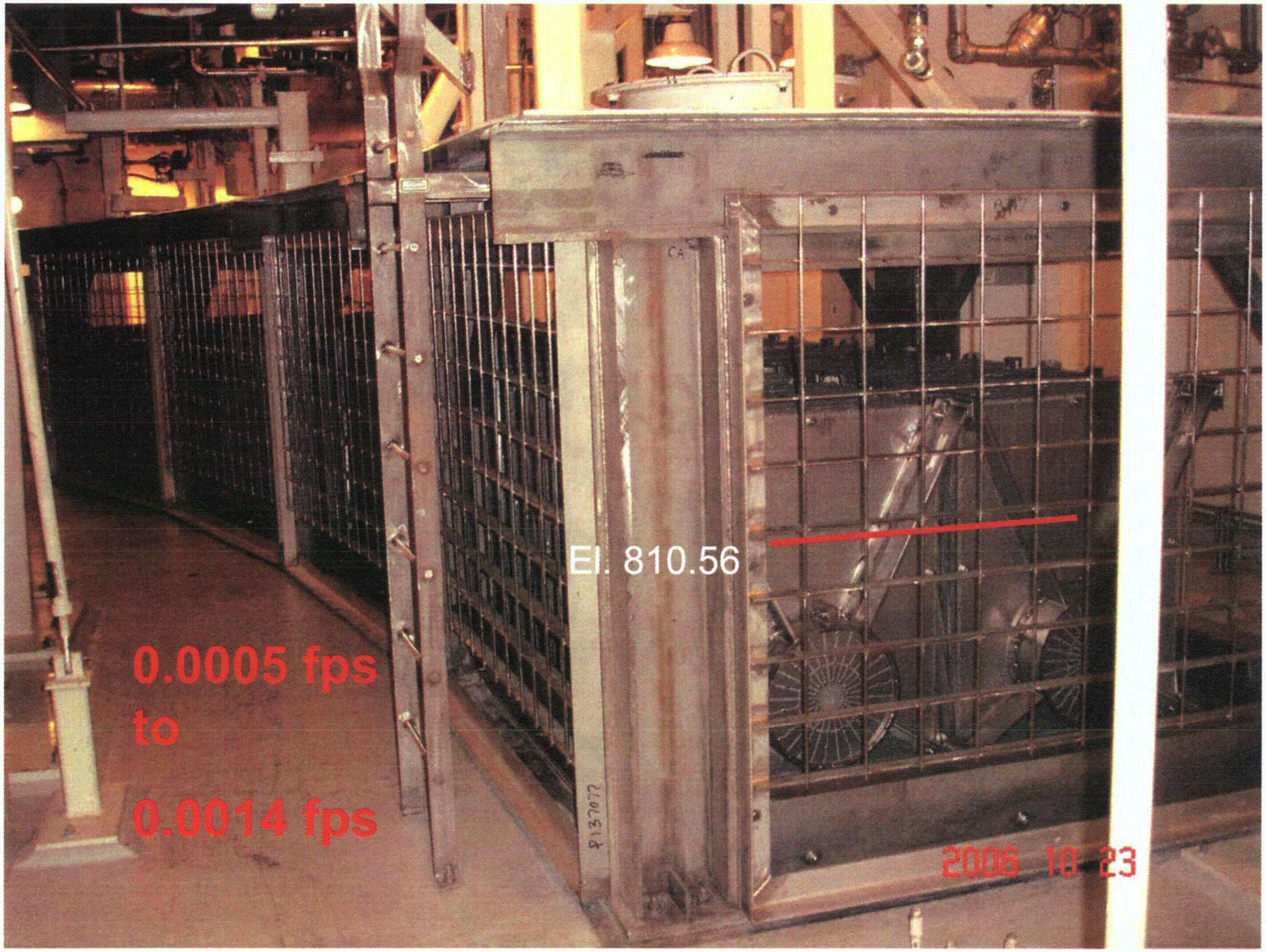
P-3.j.2-1b Core Tube



P-3.j.2-2 New Sump Strainer



P-3.j.2-2a New Sump Strainer



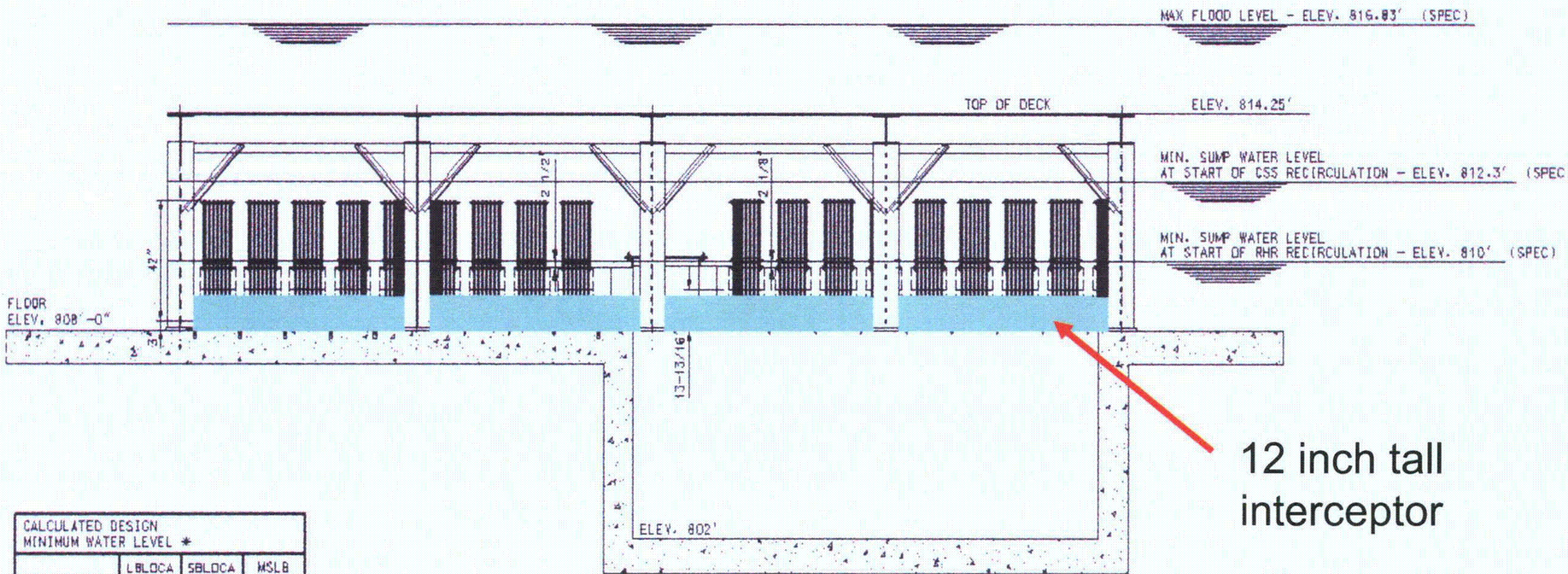
P-3.j.2-2b SBLOCA ECCS start

P-3.j.2-3 New Sump Strainer

P-3.j.2-4 New Sump Strainer

Revised calculation for ECCS Recirc for SBLOCA – 810.56 ft.

The sump pit is self venting through the strainers. There are no vents to containment above the top of the strainers.

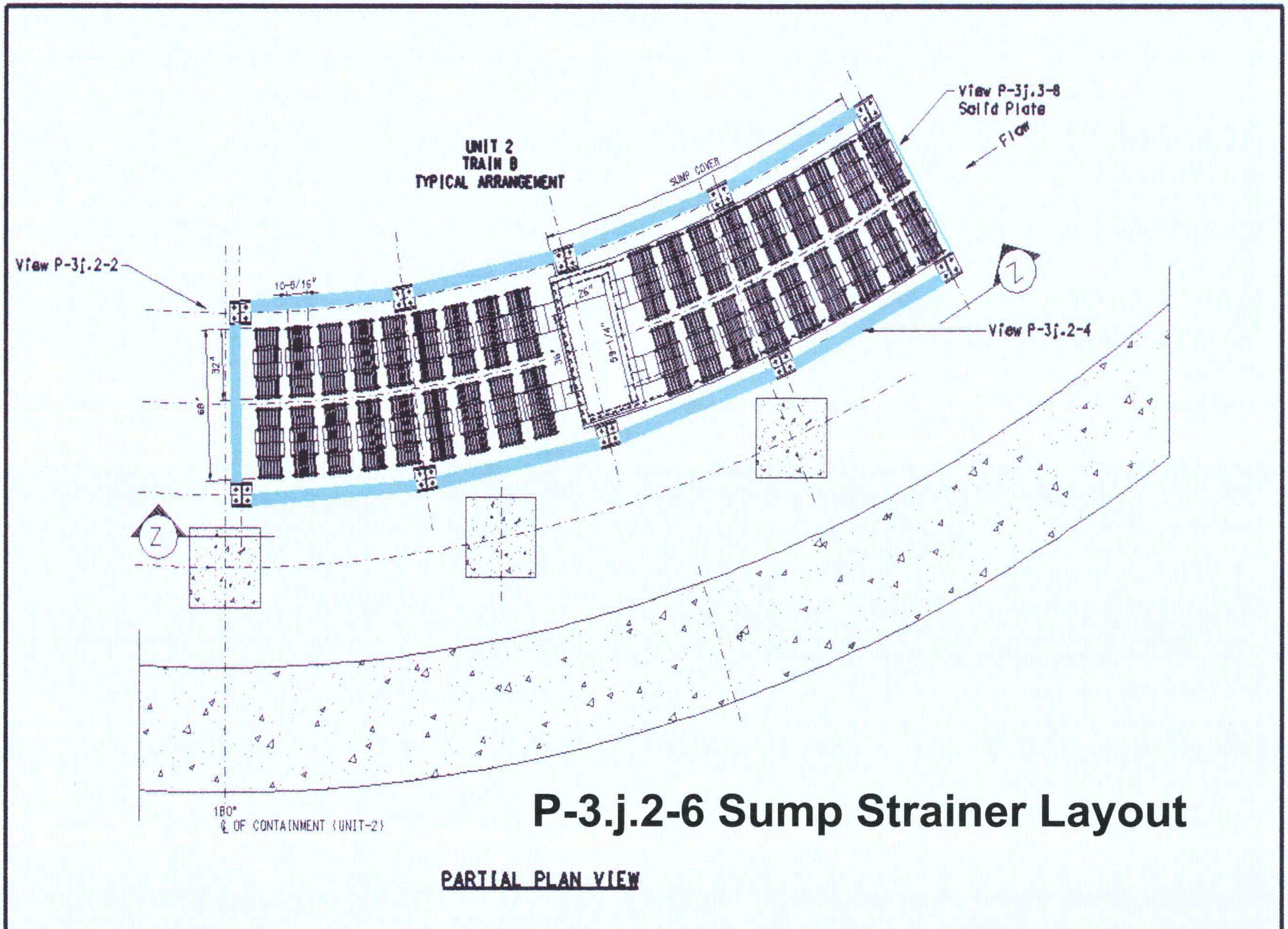


CALCULATED DESIGN MINIMUM WATER LEVEL *			
	LBLOCA	SBLOCA	MSLB
CSS RECIRC	5.21	4.55	4.64
ECCS RECIRC	3.12	2.18	N/A

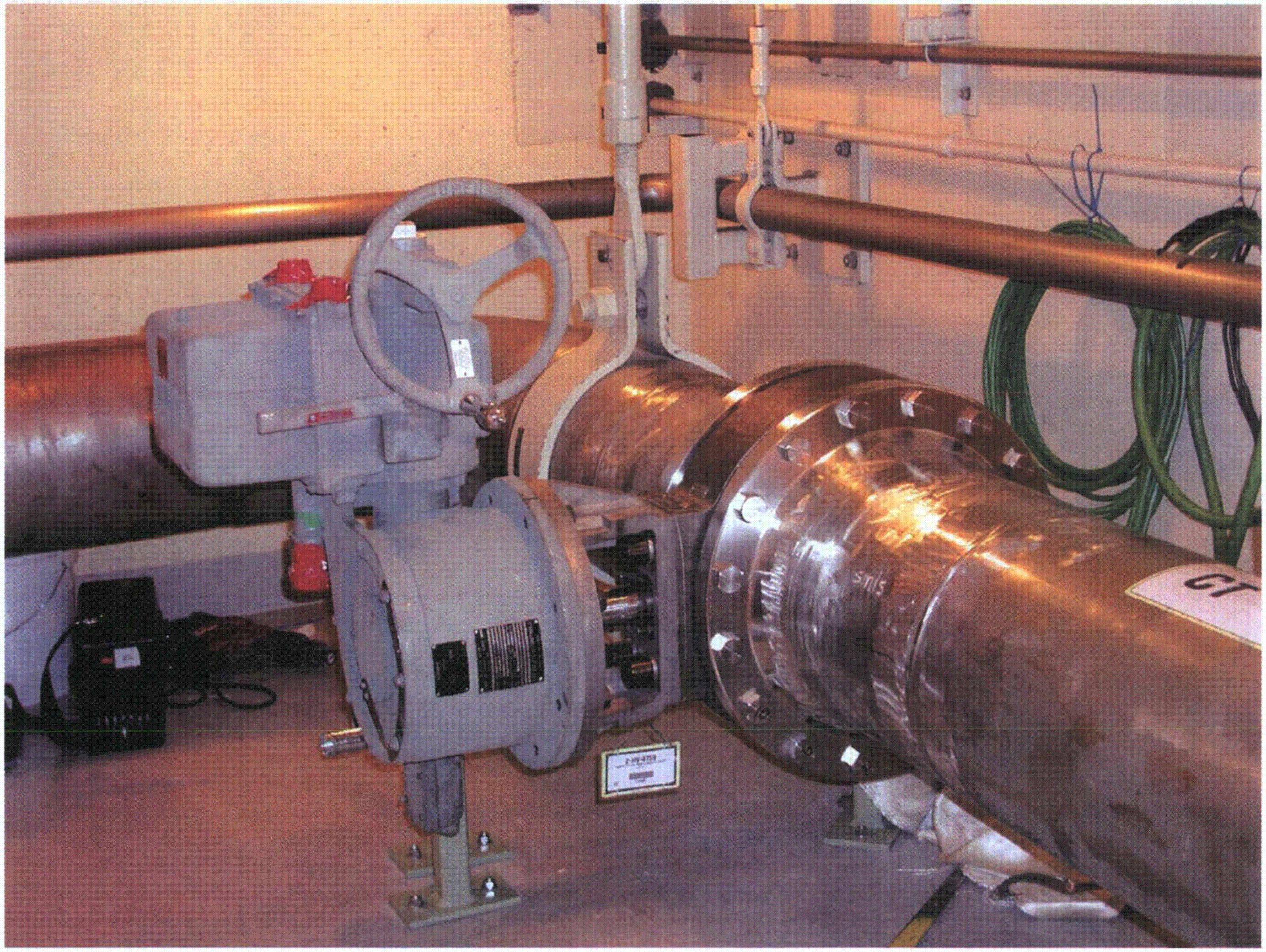
* FEET ABOVE ELEV. 808' (TWO TRAIN MINIMUM FLOOD)

ELEVATION VIEW "Z-Z"

P-3.j.2-5 Strainer/Interceptor Layout



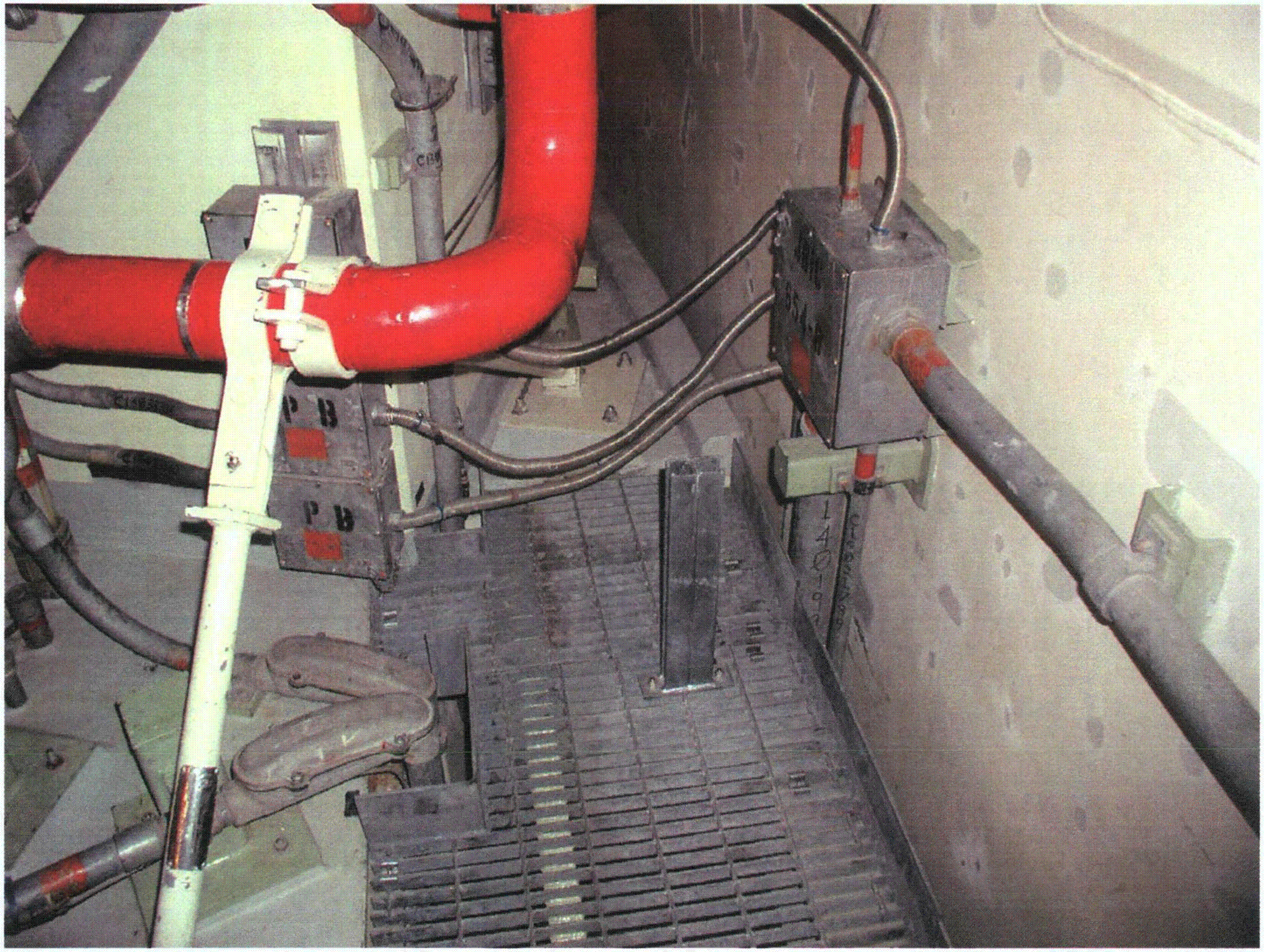
P-3.j.2-6 Sump Strainer Layout



P-3.j.3-1 MOV Modification

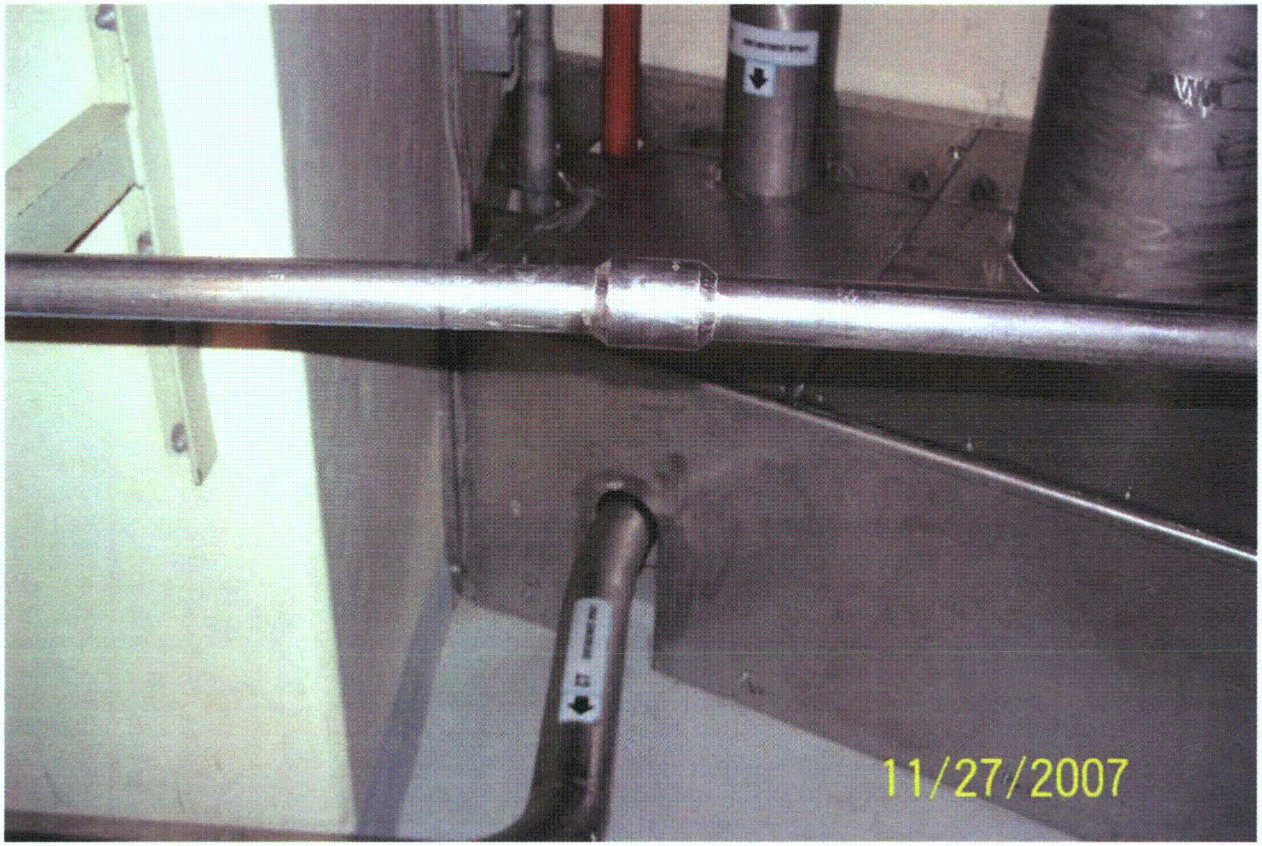
P-3.j.3-2 Equipment Drain Capped

P-3.j.3-3 Normal sump drain cover



P-3.j.3-4 El. 832 Grating and Gap

P-3.j.3-5 Flashing Mod



P-3.j.3-6 Flashing Mod

P-3.j.3-7 Flashing Mod

P-3.j.3-8 Diverter Modification