# Comanche Peak Nuclear Power Plant

# ENGINEERING REPORT

# Generic Letter 2004-02 Supplemental Response

# ER-ESP-001

# REVISION 1

SMARTFORM ENR#: ENR-2007-002743-20-01

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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 0, and submitted it to the NRC for review in June 2007. The NRC staff has reviewed WCAP-16793-NP, Revision 0, but has not issued a final SE on this WCAP because of several issues that were identified by the Advisory Committee on Reactor Safeguards (ACRS) and staff that need to be addressed. 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

In response to Generic Letter 2004-02 [Ref. 1A], 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 0, and submitted it to the NRC for review in June 2007. The NRC staff has reviewed WCAP-16793-NP, Revision 0, but has not issued a final SE on this WCAP because of several issues that were identified by the Advisory Committee on Reactor Safeguards (ACRS) and staff that need to be addressed. 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 August 2009.

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.

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

## 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. 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]. These activities were completed 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.

### 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.

- 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. This report was revised based on the completed modifications to the plant design.

- 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. 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 reviewed WCAP-16793-NP, Revision 0, but has not issued a final SE on this WCAP because of several issues that were identified by the Advisory Committee on Reactor Safeguards (ACRS) and staff (e.g., chemical effects, core inlet configuration, assumed debris loads, etc.) that need to be addressed. The CPNPP analysis and licensing basis are in accordance with WCAP-16793-NP. 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. Modifications were made to reduce the inventory of aluminum.

### 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.

Changes included:

- 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

## 2.2 Schedule

| | Corrective Action Description | Status | ECD |
|---|---|---|---|
| 1. | Containment condition assessment | Complete | |
| 2. | Replacement of Radiation Protection Locked High Rad Doors to the Steam Generator Compartments | Complete | |
| 3. | Redesign of the Drain Path to the Inactive Sump | Complete | |

| | Corrective Action Description | Status | ECD |
|---|---|---|---|
| 4. | Removal of Radiation Protection Barriers and a Tool Room enclosure | Complete | |
| 5. | Implementation of Compensatory Actions | Complete | |
| 6. | Reassessment of Containment Coatings to provide current assessment of unqualified coatings. | Complete | |
| 7. | Evaluation of the Plant Labeling Program | Complete | |
| 8. | Upstream Effects Evaluation | Complete | |
| 9. | Event Characterization | Complete | |
| 10. | Debris Generation Evaluation | Complete | |
| | Confirmation that Debris Generation bounds Units 1 and 2 | Complete | |
| | Testing to support the selection of a 4D ZOI for qualified coatings destruction pressure. | Complete | |
| | Testing to determine unqualified coating debris source terms | Complete | |
| | As-built configuration of Radiant Energy Shields | Complete | |
| | Confirmation that vapor barrier materials were not used in the fiberglass insulation applications | Complete | |
| | Identification of flexible tubing material used for RCP lube oil collection system | Complete | |
| | Revision of analysis for the above and minor open items | Complete | |
| 11. | Debris Transport Evaluation | Complete | |
| | Refinements based on new sump strainers and related design modifications | Complete | |
| 12. | Summary of Debris Generation and Transport Evaluation | Complete | |
| 13. | Downstream Effects Evaluation, Blockage | Complete | |
| | Determination of RHR Pump Seal Cooler Tube ID | Complete | |
| 14. | Downstream Effects Evaluation, Equipment Wear | Complete | |
| 15. | Downstream Effects Evaluation, Valve Wear | Complete | |
| 16. | Downstream Effects Evaluation, Reactor Vessel | Complete | |
| 17. | Downstream Effects Evaluations, Fuel | In process | August 2009 |
| 18. | Downstream Effects Evaluation, Long Term Cooling | Complete | |
| 19. | Calculation of Required and Available NPSH | Complete | |
| | Chemical effects testing. | Complete | |
| | Head loss and bypass testing on the replacement strainer utilizing the results of the site-specific debris generation and debris transportation evaluations. | Complete | |
| 20. | Strainer Replacements (and interrelated modifications) | Complete | |

| | Corrective Action Description | Status | ECD |
|---|---|---|---|
| | Pump suction pressure instrumentation | Complete | |
| 21. | Strainer Structural Analysis | Complete | |
| 22. | Potential or Planned Design/Operational/Procedural Changes | | |
| | Revision to design control procedures | Complete | |
| | Revision to Design Basis Documents and engineering specifications | Complete | |
| | Revision to the Coatings Program | Complete | |
| | Revision to the Station Labeling Program | Complete | |
| 23. | Enhancements to the procedures and programs to further assure control of potential debris | In process | August 2009 |

**Section 3.0 Specific Information Regarding Methodology for Demonstrating Compliance**

Responses to 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" [Ref. 1.C] are denoted in the margin (e.g. RAI #).

**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.

Revision 1 changes to this section are NOT annotated.

RAI 33 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 SER [Ref. 4.A], piping under 2 inches diameter can be excluded when determining the limiting break conditions. Therefore, the locations where LOCA can occur are limited by the design.

<u>Exception(s) Taken to GR and SE for Break Selection</u> - 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.

<u>CONSERVATISM:</u> 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.

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 LOCA bound all small break LOCAs for debris sources and debris generation.

<u>CONSERVATISM:</u> The break selection was performed to bound both units for each debris source.

### 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 compliance with 10CFR50, GDC-38 for containment heat removal.

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).

RAI 19 The CPNPP licensing basis for break selection for secondary line breaks is BTP MEB 3-1 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 was based on 10CFR50.46 which is 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 SER Supplement 9, Appendix L, the NRC Staff addressed insulation debris as evaluated in 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. 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. However, because the emergency sumps 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 pipe 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.. 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 RCS 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.

- 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.

**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.

Revision 1 changes to this section are NOT annotated.

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.

### 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 LOCA, 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 sheet thickness of 0.125 inches [Ref. 3.B]. 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.]

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 $ft^3$

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**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 the low density fiberglass has a lower destruction pressure than the materials with a higher density (i.e. CPSES anti-sweat insulation), it is conservative to model the anti-sweat insulation as Nukon™, Thermal-Wrap™, and Knauf™ LDFG.

RAIs 35 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 | 10.0-18.6 psi ZOI | 6.0-10.0 psi ZOI |
| | (7.0 L/D) | (11.9-7.0 L/D) | (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 (covered) 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 ft3 | 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 $ft^3$ |

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### 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.

Therefore, there is one blanket per layer per linear foot. 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. The destruction test configuration used three (3) blowdown tests: one with a hanging blanket on an open back test rig and two with a hanging blanket on an open back test rig. CPNPP uses blankets that are secured with substantial stainless steel bands. 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

Within the 3.0D ZOI, based on review of test observations, it is concluded 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)5.3 $ft^3$ (642 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 $\{r_{12\text{" pipe}} / r_{target}\}$
Where: $P_{dest}(i)$ = the destruction pressure for RMI of outer radius $r_{target}$
$r_{12\text{" pipe}}$ = 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:
$r/D = (7149 * \{7.04 \text{ in.}/ r_{target}\} /4.19)^{1/3}$

$= 11.95\{7.04 \text{ in.}/ r_{target}\})1/3$ 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 | 10.0-18.6 psi ZOI | 6.0-10.0 psi ZOI |
| | (9.2 L/D) | (10.4-9.2 L/D) | (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% |

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### 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. 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 psi which is the lowest damage pressure of materials provided in the URG (11.A) and is considered conservative.

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.

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 were considered Acceptable Labels. 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..

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 included in transport testing 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.

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 $ft^2$ | 86.5 $ft^2$ |
| 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.

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.

Revision 1 changes to this section are NOT annotated.

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 Charactreistics**

**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% small pieces in accordance with the NEI GR.

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 $(0.65 \times 137 + 0.15 \times 262)/0.8 = 161$ 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 the manufacturer Thermal Ceramics, Inc, Min-K fails as 20% fiber fines and 80% particulate fines based on information provided in Attachment A. 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

**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.1.5 Coatings**

See Section 3.h.

**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 prior to Mode 4 entry |
| 2007, August | Unit 1 - at power (post 1RF12) |
| 2008, October | Unit 1 - 1RF13 after Mode 4 procedure entry |

**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 performed 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. 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. 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 $ft^{-1}$. 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.

<u>CONSERVATISM:</u> Note that the assumptions for latent debris result in a significant conservatism in the quantity and characteristics of latent fiber.

### 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.

Revision 1 changes to this section are NOT annotated

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 selected 3.e-1 through 3.e-6 in Attachment E for selected figures from Debris Transport Calculation [Ref. 7.A.3].

### 3.e.1 Methodology

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. A three-dimensional computer aided drafting (CAD) model (e.g. Figure 3.e-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.

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] and tumbling tests [Ref. 7.A.7] 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

RAI 43 A 10% erosion of fiberglass was used 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. A 10% erosion of fiberglass was assumed based on analysis in the debris transport calculation. Erosion testing by Alion [Ref. 7.A.13] that confirmed the 10% assumption was compared to CPNPP materials and conditions [Ref. 7.A.12] and it was concluded that the testing was applicable to CPNPP.

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

RAI 38 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-3 along with the cases for secondary line breaks. Features that were significant to transport were modeled (see Figure 3.e-3 and 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-5 and 3.e-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 IOZ paint 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.

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 $ft^3$<br>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 $ft^3$<br>110.89 lbs | 0.78 | Single Train Sump B | Loop 4 Main Piping |
| Anti-sweat Fiberglass Large (@ 4.9 lb/ft3) | 2.28 $ft^3$<br>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 $ft^3$<br>11.27 lbs | 0.16 | Two Train Sump A | Surge Line Break in Loop 4 Compartment |
| Lead Blanket Covers Fiberglass Fines | 0.34 $ft^3$<br>26.84 lbs | 0.93 | Single Train Sump A or B | Loop 1 Cold Leg |
| Lead Blanket Covers Fiberglass Large | 0.00384 $ft^3$<br>0.306 lbs | 0.16 | Two Train Sump A | Loop 1 Cold Leg |
| Lead Blanket Lead Wool Fines | 0.215 $ft^3$<br>25.84 lbs | 0.29 | Two Train Sump A | Loop 1 Cold Leg |
| Min-K Fines (Fibrous portion) | 0.10 $ft^3$<br>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 $ft^3$<br>6.72 lbs | 0.93 | Single Train Sump A or B | Surge Line Break in Loop 4 Compartment |
| Acceptable Epoxy Paint (inside ZOI) | 262.91 lbs | 0.93 | Single Train Sump A or B | Loop 4 Main Piping |
| Acceptable IOZ Paint | 376.00 lbs | 0.93 | Single Train | 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 |
| (inside ZOI) | | | Sump A or B | |
| 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) Small(1/8"-1/4",1/4"-½", 1/2"-1") | 223.95 lbs | 0.07 | Two Train Sump A | Loop 4 Main Piping |
| 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 IOZ (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 |

| Bounding Debris Load for All LOCA Conditions [Ref. 7.A.5] | | | | |
|---|---|---|---|---|
| Debris Type | Bounding Debris Load | Transport Fraction | Bounding Operating Condition | Bounding Break Location |
| 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 |
| | | | | |

### 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 the 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].

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 | Bounded by previous 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$^3$<br>42.6 lbs | 1.00 | 98.3 ft$^3$ @ 5.5 lb/ft$^3$<br>540.65 lbs | Yes |
| Anti-sweat Fiberglass Small (@ 4.9 lb/ft3) | 32.67 ft$^3$<br>160.0 lbs | 0.94 | | |
| Anti-sweat Fiberglass Large (@ 4.9 lb/ft3) | 0.00 ft$^3$<br>lbs | 0.01 | 0.00 ft$^3$ | N/A |
| Anti-sweat Fiberglass Jacketed (@ 4.9 lb/ft3) | 0.00 ft$^3$<br>lbs | 0.00 | 0.00 ft$^3$ | N/A |
| Kaowool | 44.2 ft$^3$<br>353.6 lbs | 1.00 | 56.1 ft$^3$<br>448.8 lbs | Yes |
| Sil-temp | 0.88 ft$^3$<br>52.4 lbs | 1.00 | 1.2 ft$^3$<br>71.4 lbs | Yes |

| Bounding Debris Load for MSLB Conditions [Ref. 7.A.5] | | | | |
|---|---|---|---|---|
| Debris Type | Bounding Debris Load | Transport Fraction | Prototype Test Debris Load | Bounded by previous test |
| Min-K Fines (Fibrous portion) | 0.81 $ft^3$<br>12.96 lbs | 1.00 | 0.5 $ft^3$<br>30 lbs | Yes |
| Min-K Fines (Particulate portion) | 3.26 $ft^3$<br>52.16 lbs | 1.00 | 34.3 lbs | No |
| Acceptable Epoxy Paint (inside ZOI) | 217.5 lbs | 1.00 | 3860.9 lbs | Yes |
| Acceptable IOZ Paint (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 | | |
| Unqualified IOZ (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 |

| Bounding Debris Load for MSLB Conditions [Ref. 7.A.5] | | | | |
|---|---|---|---|---|
| Debris Type | Bounding Debris Load | Transport Fraction | Prototype Test Debris Load | Bounded by previous test |
| 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 |
| | | | | |

RAI 19 The above comparison shows that the prototype testing conservatively bounded the current debris generation and transport results for both fiber and particulate. Prototype testing showed that LOCA test condition bounded the MSLB testing. Design basis secondary line breaks do not involve ECCS recirculation or almost all of the fibrous debris calculated above. The mission time is less than one day [Ref. 7.F.22] giving little time for chemical effects.

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.

Revision 1 changes to this section are NOT annotated.

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] |
| 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 performance issue. (See Section 3.j for details)

RAI 42 The minimum specified 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. 8.A.1. The specified flood levels are lower than the calculated 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".

| | | |
|---|---|---|
| SBLOCA Minimum Sump Water Level at start of CSS recirculation | Elevation 812.3 ft (4.3 ft. above the 808' floor elevation) | >/= 0.55 ft submergence (Note 1) |
| LBLOCA Minimum Sump Water Level at start of CSS recirculation | Elevation 813.0 ft (5.0 ft. above the 808' floor elevation) | >/= 1.25 ft submergence |

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.

The minimum water level at ECCS switchover 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. 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. Therefore, the period of time the strainers are not fully submerged with partial flow is very short (i.e., the stariner will be fully submerged in less than 15 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..

### 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) |
| $NaAlSi_3O_8$ 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.

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] as revised by WCAP-16785-NP Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model [Ref. 6.C] with further clarification from the PWROG.

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

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.

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

Debris Preparation and the selection of test surrogates were in accordance with SFSS-TD-2007-004, Testing Debris Preparation and Surrogates [Ref. 8.D.4].

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 dirt mix |
| 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 |
| 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 |

| Debris Type | Surrogate |
|---|---|
| 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 Crieria

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 containments. 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
Flow through SFS Module = 363 gpm
Velocity through SFS Module = 0.0074 ft/sec
Velocity through Test Flume = Varies as described below

RAI 39 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) .

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.

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).

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

### 3.f.3.3 Testing, Results and Conclusions

Five 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.

For Test 4, design basis debris loaded head loss test, 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. A

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.

Head Loss Extrapolation

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, and the extrapolated head loss for 30 days (T=2,592,000 sec) using the linear curve fit is 4.2552 ft of water.

Attachment D shows the debris interceptor curb during flume drain down. Tin powder and 1/64$^{th}$ 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.

- **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** - 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. 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.

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. It was concluded that these debris constituents would not transport to the strainer 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

RAI 41 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 |

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

Calculation: 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 determination 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]

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 Recircualtion |
|---|---|---|
| LBLOCA | El. 811.12 | El. 813.21 |
| SBLOCA | El. 810.18 | El. 812.55 |
| MSLB | N/A | El. 812.64 |

Note that SBLOCA bounds MSLB in that the flood level is lower and the flow rates are higher. 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.

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 (if spray has been initiated) 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.

- *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 and 11.38 ft once spray recirculation is initiated. [Ref. 7.F.19]

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

Therefore, the spray pumps margin is the limiting element. The maximum total strainer head loss extrapolated to 30 days at 212 °F is 1.55 feet yielding a conservative minimum NPSHa margin of 5 feet.

Conservatism - Both of the clean strainer 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.

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.

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## Section 3.h Coatings Evaluation

The coatings evaluations performed 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, CZ-11/Phenoline 305 for steel and Nutec 11S/Nutec 11/Nutec 1201 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.

The reevaluation of all declassified coatings inside containment was performed under SMF-2004-002882-00 [Ref. 3.E]. The suitability for application review of applied protective coatings was performed by ER-ME-124, "Evaluation of CPSES Protective Coatings" [Ref. 5.E].

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 | | |
|---|---|---|
| **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.

<u>CONSERVATISM:</u> 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.

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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]

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.
- All steel coatings within a 10D ZOI were conservatively assumed to be DBA-unqualified. Therefore, a 10D ZOI was assumed for debris generation.

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 μm 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<br>37.1% - 15.6 mils (1/64" chips)<br>and<br>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.

<u>OEM Coatings</u>

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.

CONSERVATISM: 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.

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### 3.h.4 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**

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.

Revision 1 changes to this Section are NOT annotated.

### 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 under SMF-2007-002743 (Ref. 3.J)

### 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 under SMF-2007-002743 (Ref. 3.J)

### 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-3.1.1-6 (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.

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### 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.

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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.

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]

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.

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.

Pictures P-3.j.2-2, P-3.j.2-3, and P-3.j.2-4 (Attachment A) are plant views of new strainers post installation.

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 Performance 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]

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. A solid panel was provided on the outboard ends to divert high velocity water from direct impingement on the strainer array. The side towards the containment liner is open.

## 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)<br>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 3.1 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.

### 3.1.1 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.

### 3.1.2 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 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.

Drain strainers were selected rather than debris screens since the existing drain covers used during refueling could be subject to blockage by fibrous debris during a DBA. The design uses stacked disks to provide approximately 70 $ft^2$ 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.

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 are 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.

Revision 1 changes to this section are NOT annotated.

RAI 31 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 ($\gamma$) 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

Conservatism - 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.

Conservatism - 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 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 fiber bypass assumption was overly conservative and that the bypass test data would be used in the debris ingestion calculation. The bypass percentage 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 deformable 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 performance 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).

<u>CT Pump</u>

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.

Revision 1 changes to this section are NOT annotated.

RAI 31 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 preclude 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.

### 3.n.3 In Vessel Effects - Long Term Core Cooling

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. 6.J.

[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 reviewed WCAP-16793-NP, Revision 0, but has not issued a final SE on this WCAP because of several issues that were identified by the Advisory Committee on Reactor Safeguards (ACRS) and staff that need to be addressed. 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.

Revision1 changes to this Section are NOT annotated.

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)

RAI 2 A comparison of CPNPP materials to Integrated Chemical Effects Tests (ICET) 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.

RAI 3 Aluminum scaffold materials were removed from containment at the end of 1RF12 and 2RF09.

RAI 5 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.

RAI 6 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.

RAI 7 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 the inventory.

RAI 4 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.

RAI 9 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 (Ca3(PO4)2)** | **Total Sodium Aluminum Silicate (NaAlSi3O8)** | **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) |
| | NaAlSi3O8 Precipitate | 173.2 (42 ppm) |
| | AlOOH Precipitate | 70.5 (17 ppm) |

RAIs 9, 15 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 (pH impact) in the future [Ref. 2.C.2]. The total precipitate projected for a reduction of NaOH concentration is 119.6 lbs. No time table has been established for implementation of buffer concentration reduction.

RAIs 8, 10, 11, 12, 13, 19

### 3.o.3 Qualification of Emergency Sump Strainer with Chemical Effects

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 amd RG 1.82 [Section 3.g.1].

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.

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.

**3.p.1 Changes to the Technical Specifications**

License Amendment 129 approved LDCR-TS-2005-003 [REF. 2.C.1]

- 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]

- 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 will be 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 thermal 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. #.α") 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. [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.

## 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. [CPSES-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

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]

### 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-2008-001958-00: “Inappropriate exposed materials identified inside the RCS Loop rooms”

3.L SMF-2008-003229-00: “Kaowool backing for joint gap seal found in Unit 1 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.
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 0 dated May 2007

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.

## 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 Leter 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.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.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 3.

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 ME-CA-0000-5319, Reactor Cavity Fill Rate, Revision 0

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.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.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 Performance 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, Testing Debris Preparation and Surrogates, Rev 2 dated 8/26/2008. [Proprietary] [VDRT-3584920] [Proprietary]

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.

**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.

**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.

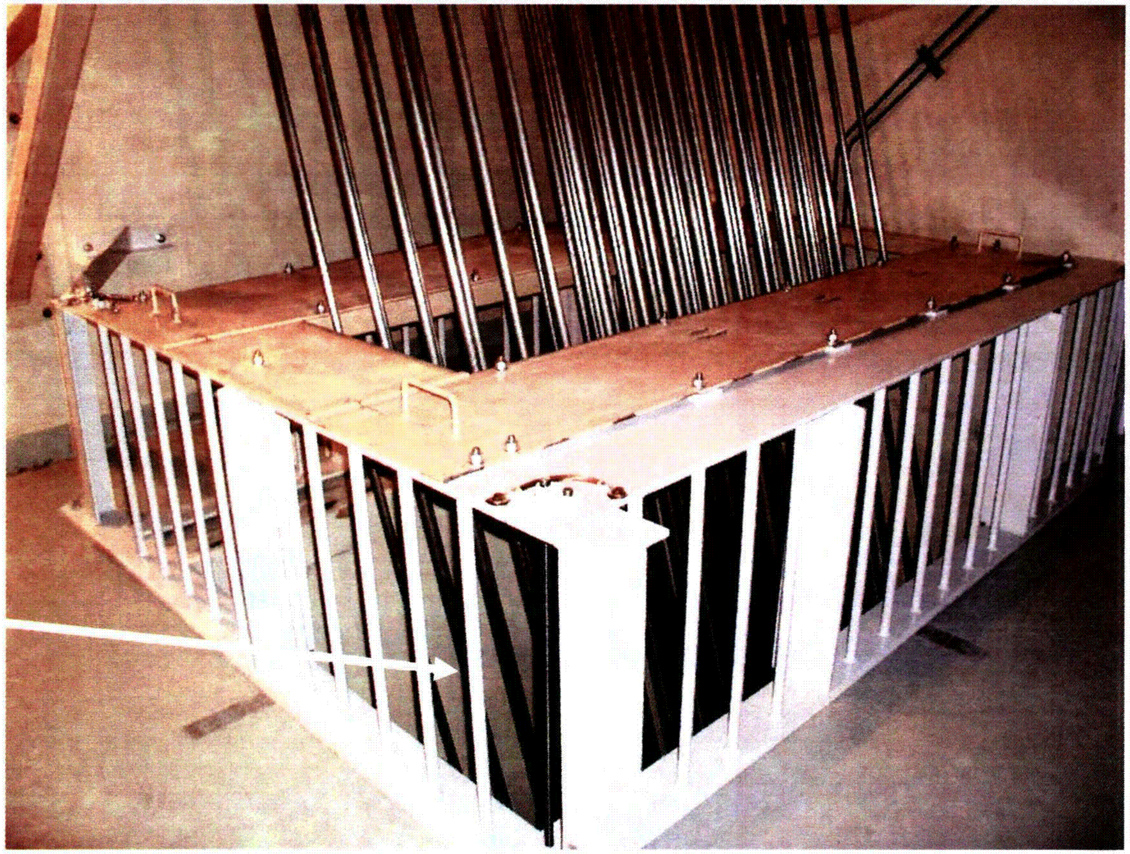
# Containment Emergency Sump Modifications

**Incore Instrumentation Guide Tube Room**


# P-3.e.1-1 Door to Inactive Sump

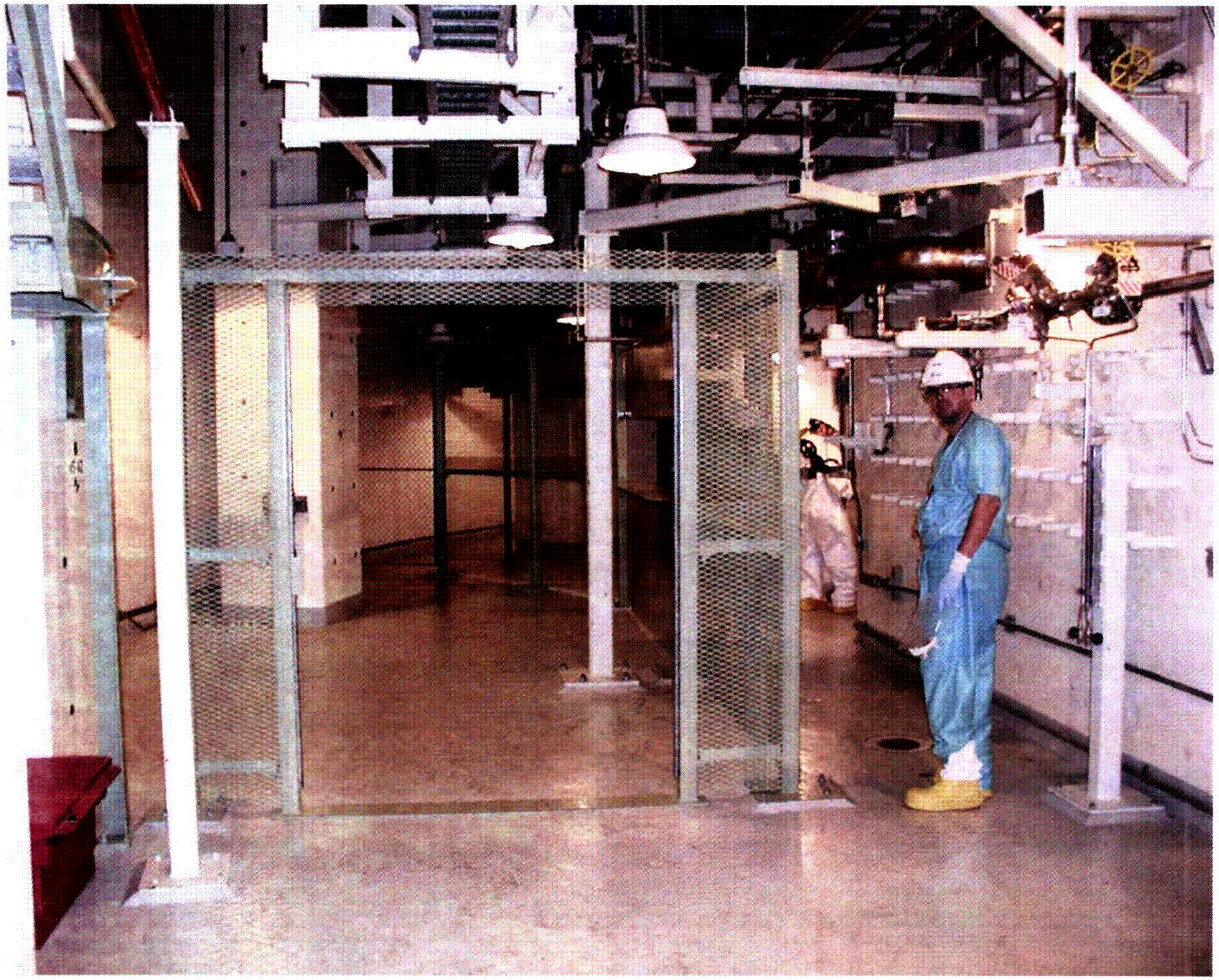

# P-3.e.1-2 Drain to Inactive Sump

**Modified**

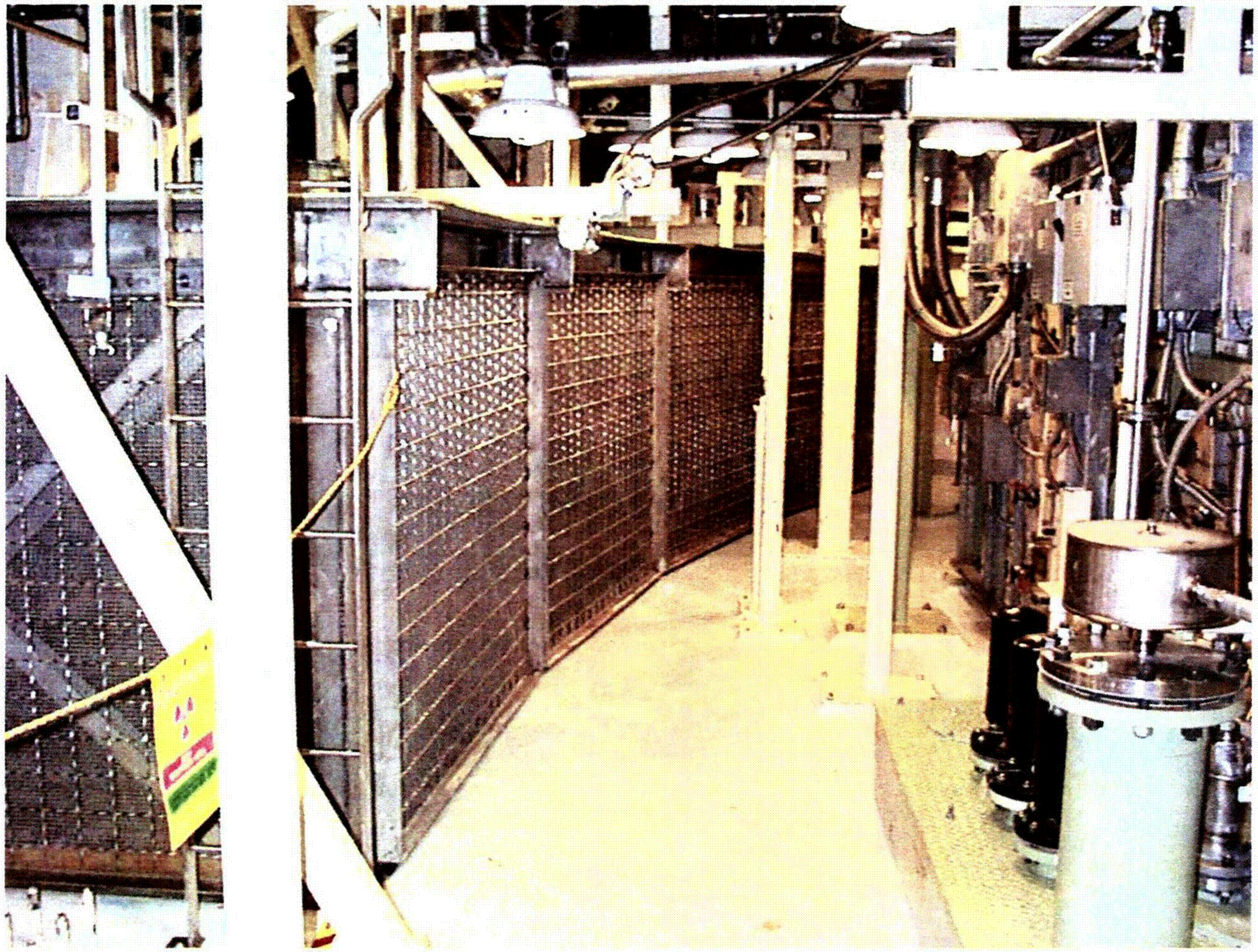


# P-3.e.1-3 Drain to Inactive Sump

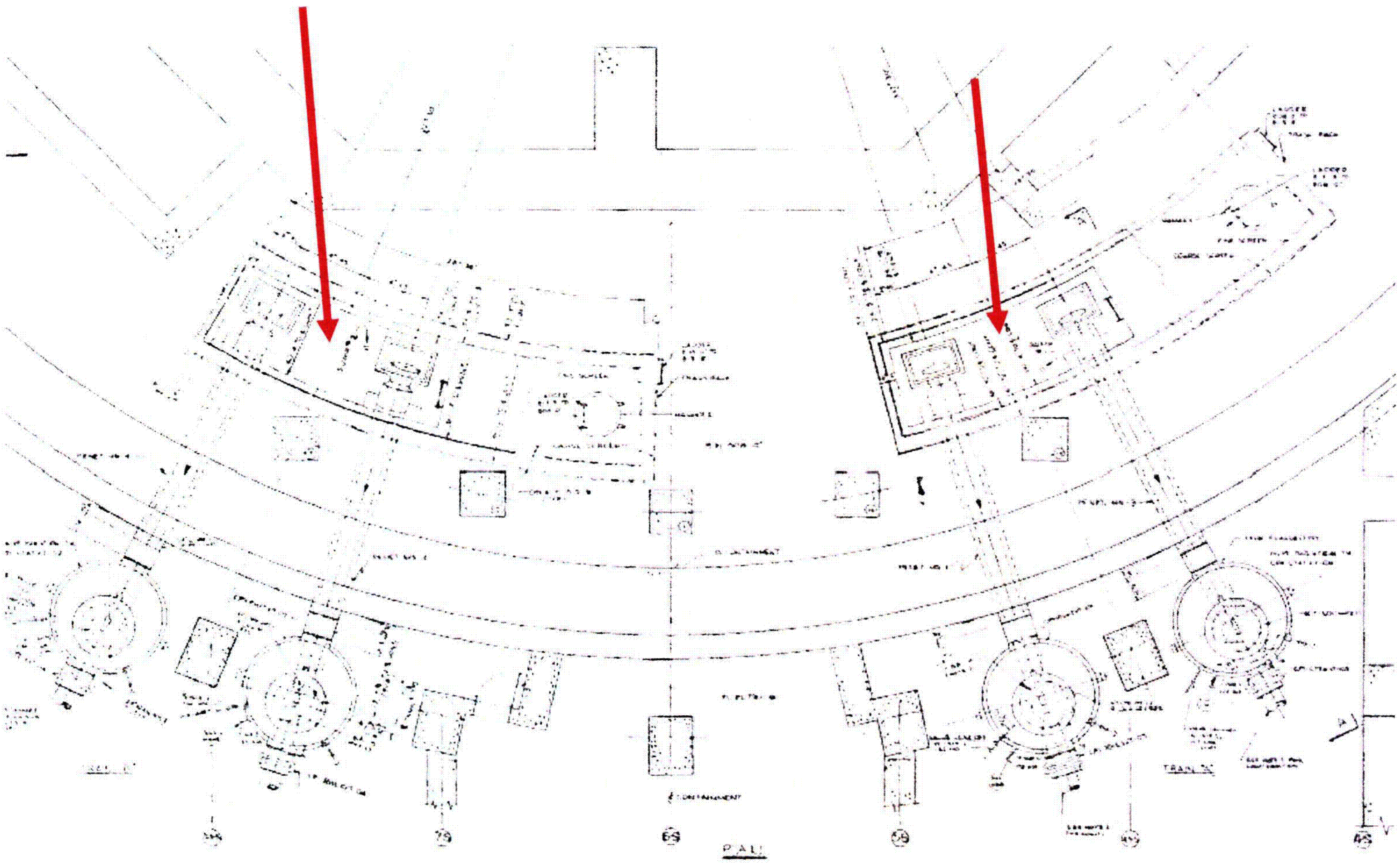
# P-3.e.1-4 Wire Mesh Cage



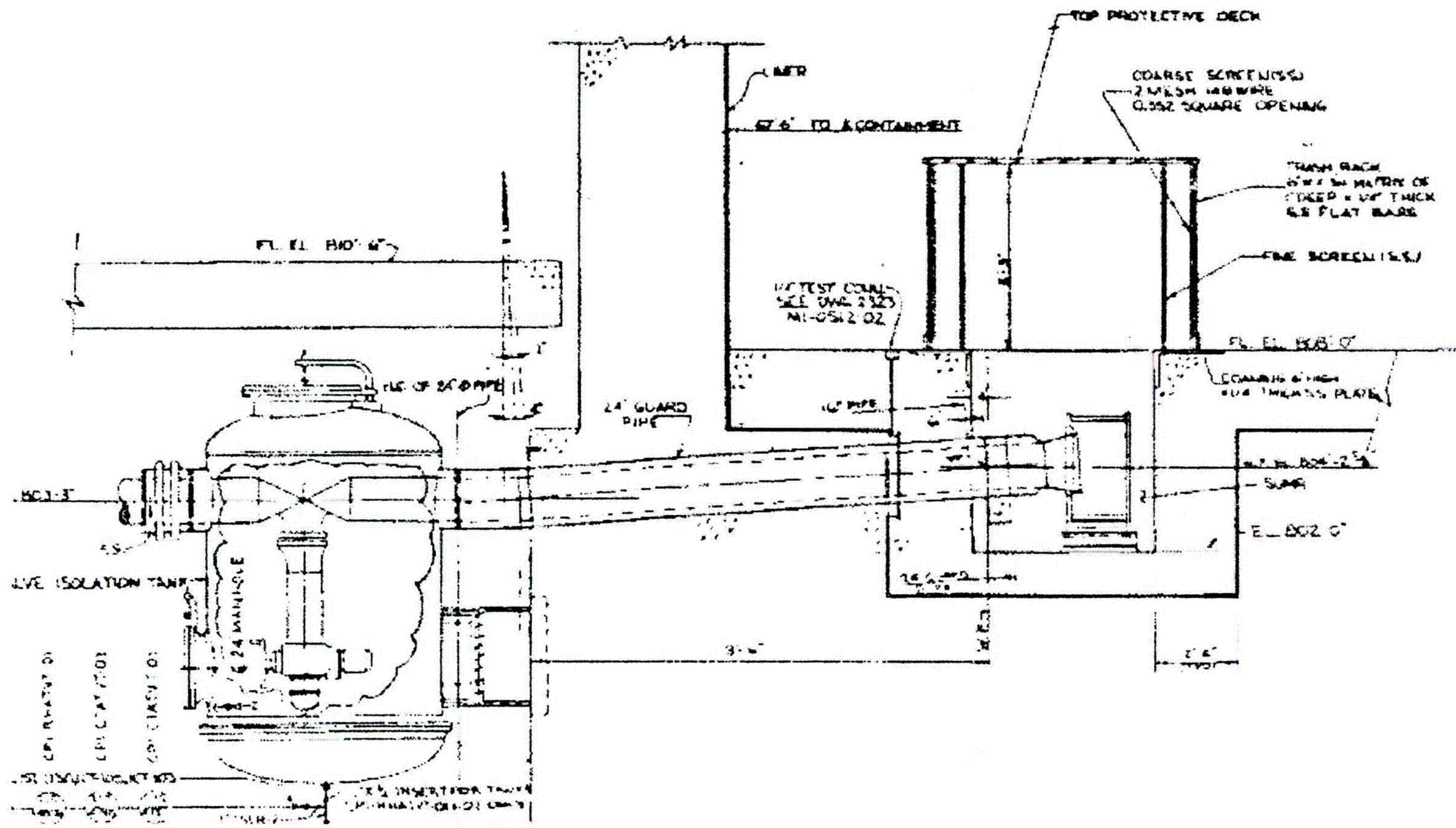
# P-3.e.1-5 Unit 2 Tool Room



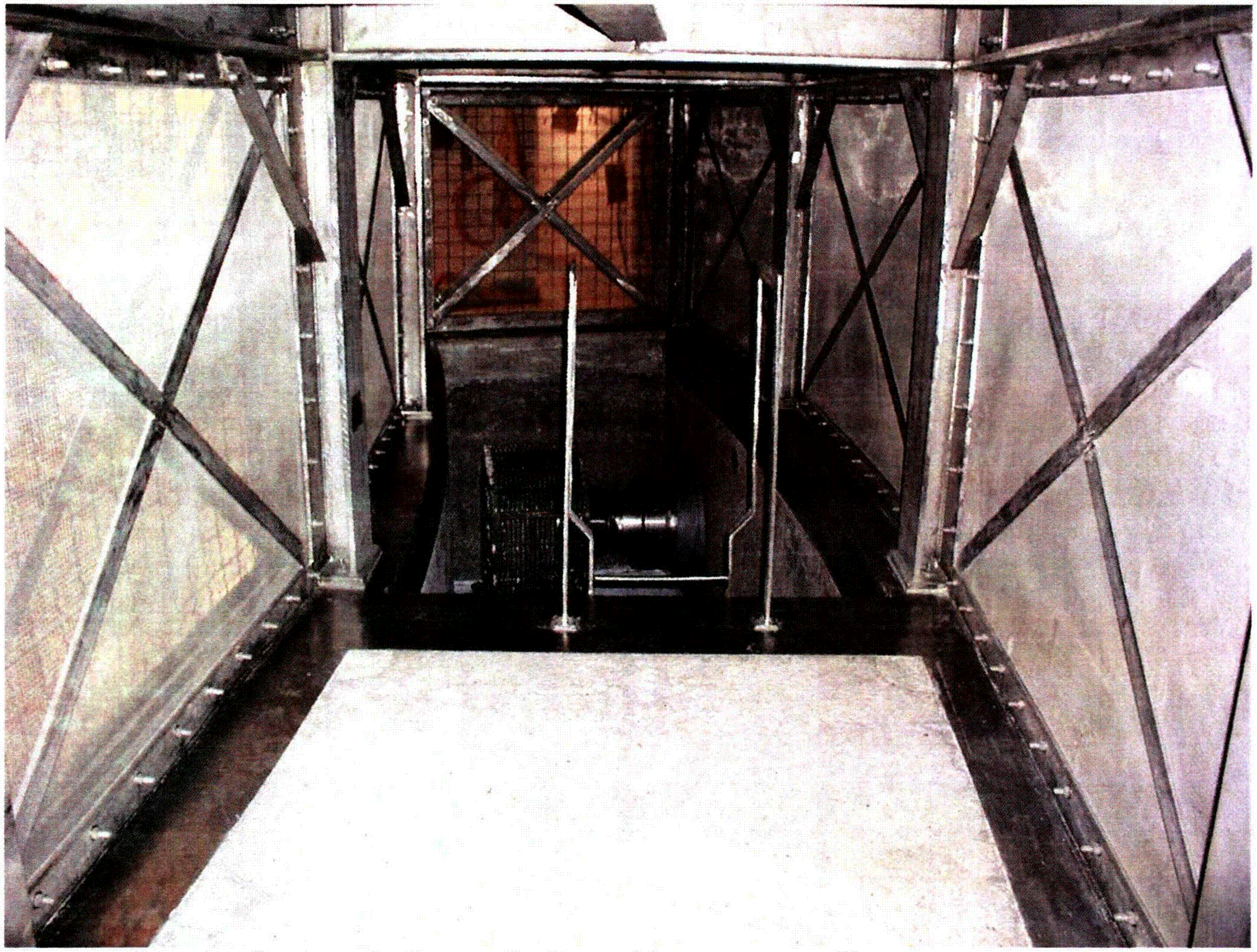
# P-3.j.1-1 Original Sump Screens



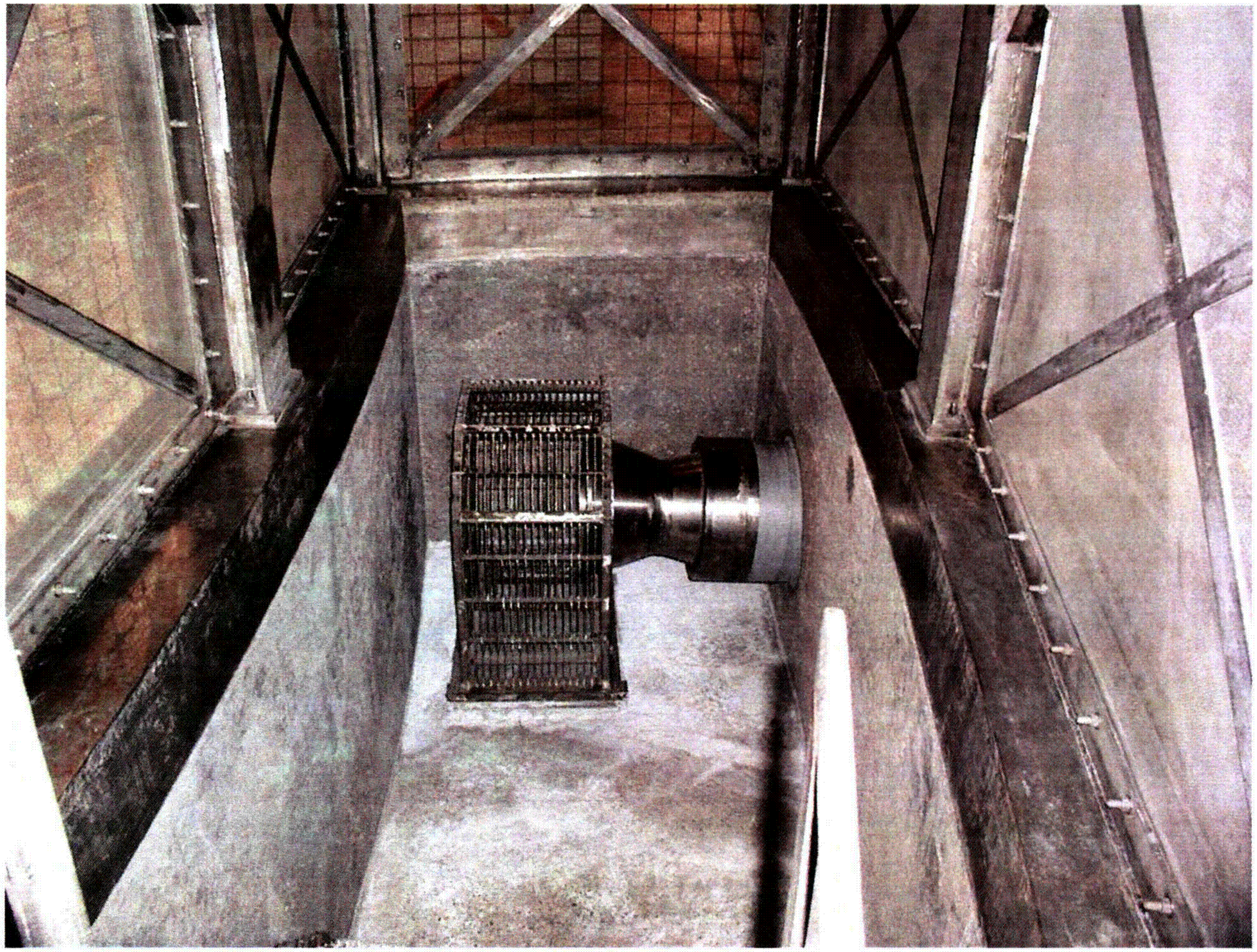
# P-3.j.1-2 Emergency Sump Arrangement



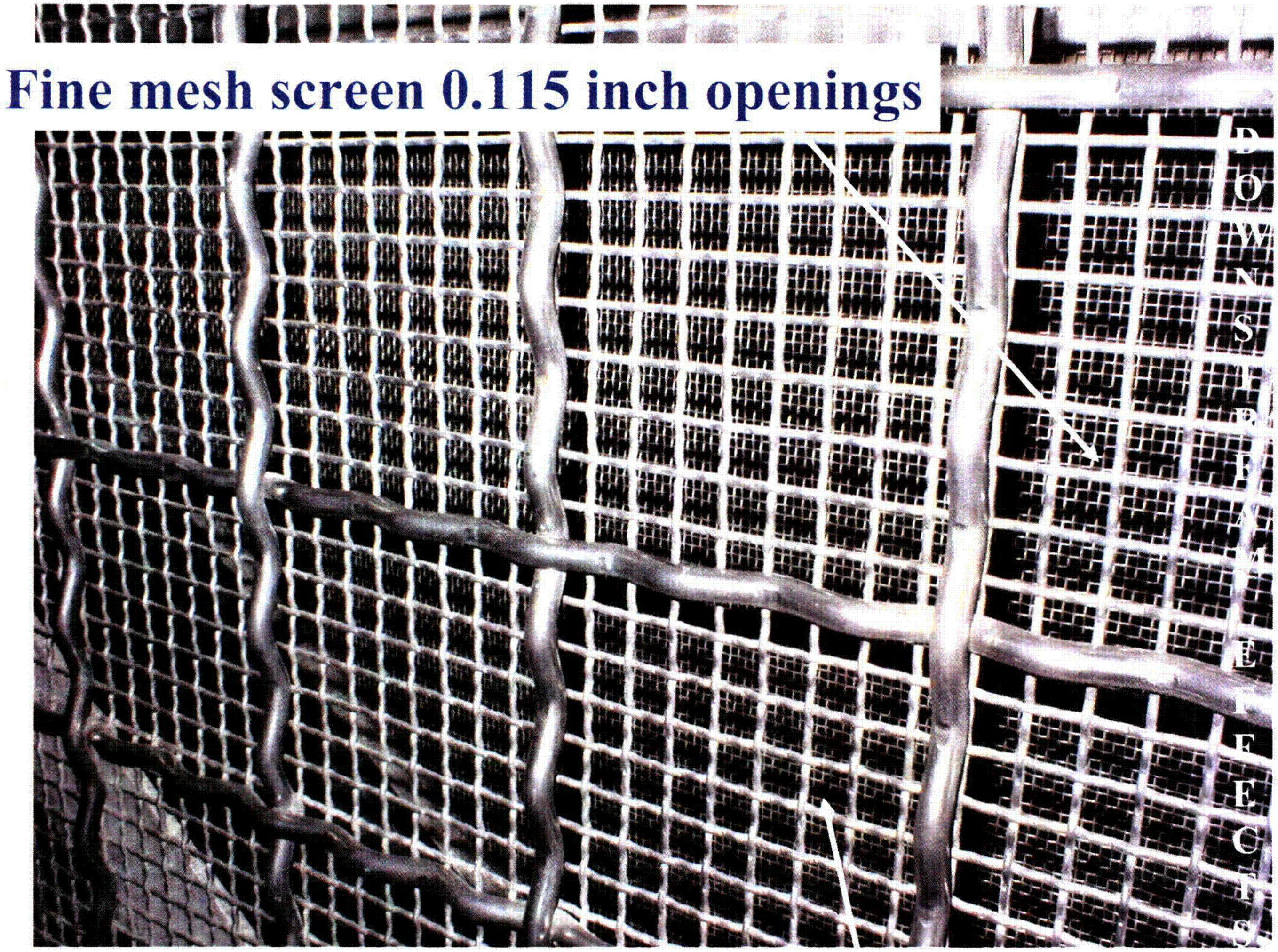

# P-3.j.1-3 Emergency Sump Arrangement



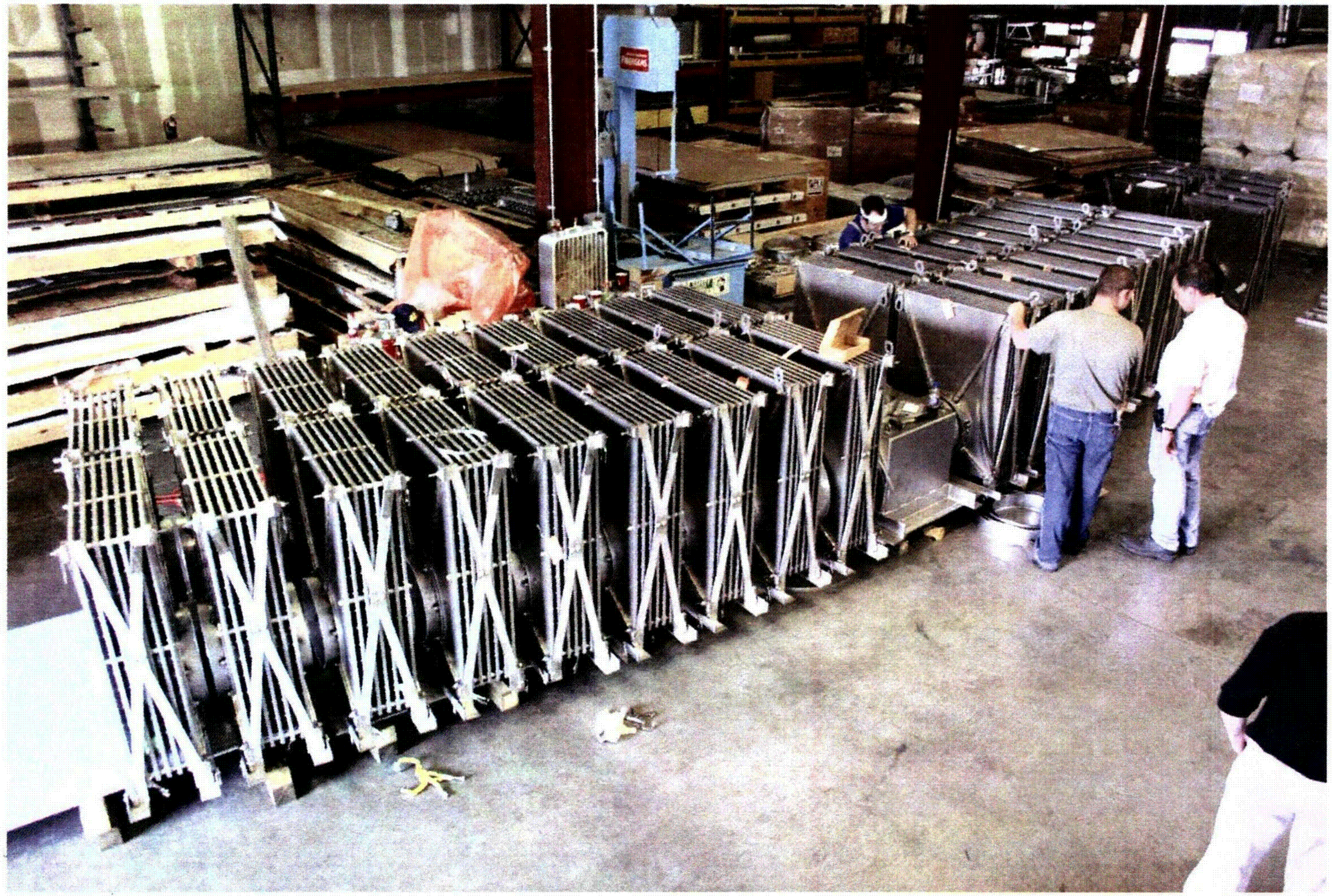
**P-3.j.1-4 Inside Sump Screens**



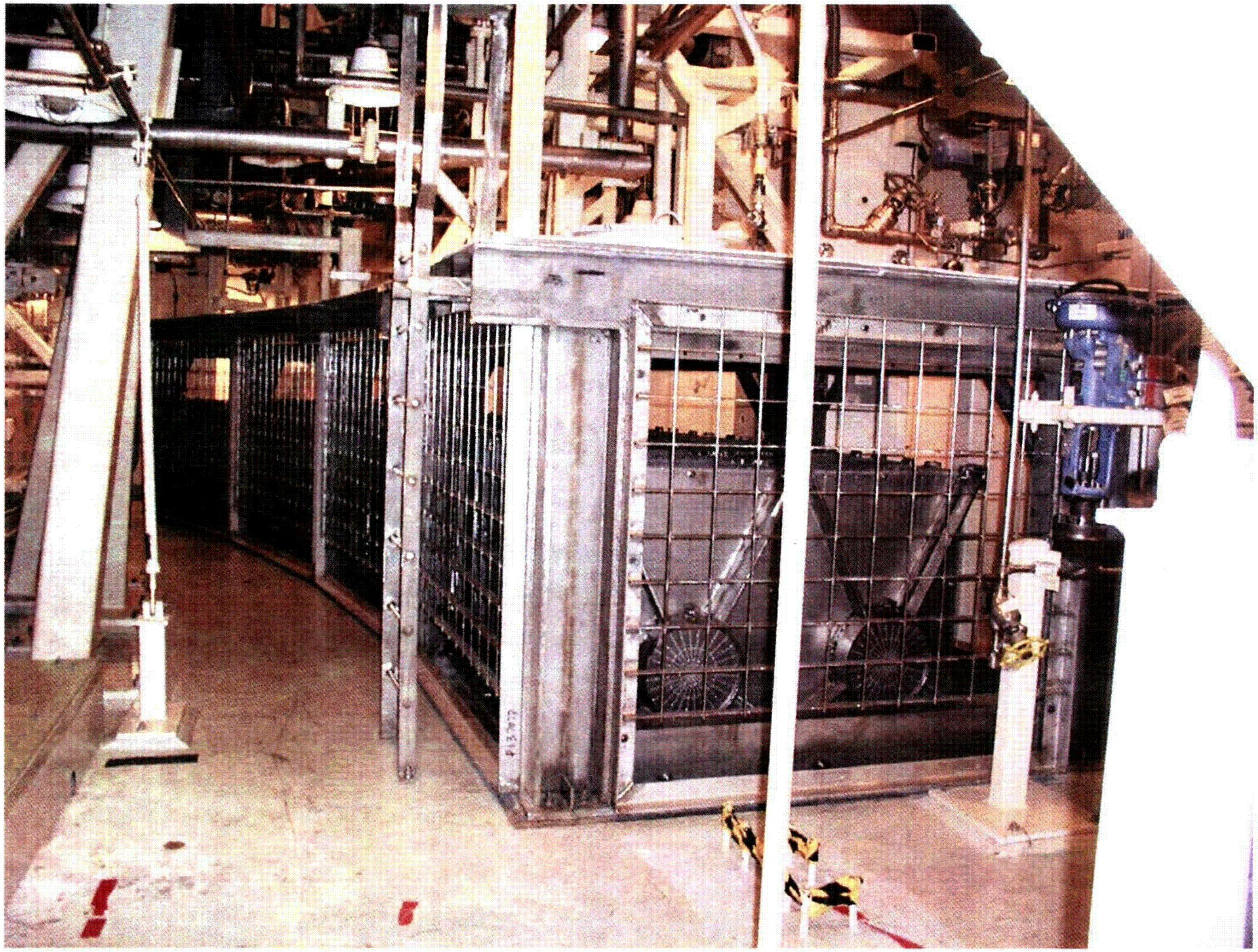
# P-3.j.1-5 Vortex Suppressor




# P-3.j.1-6 Original Sump Screens



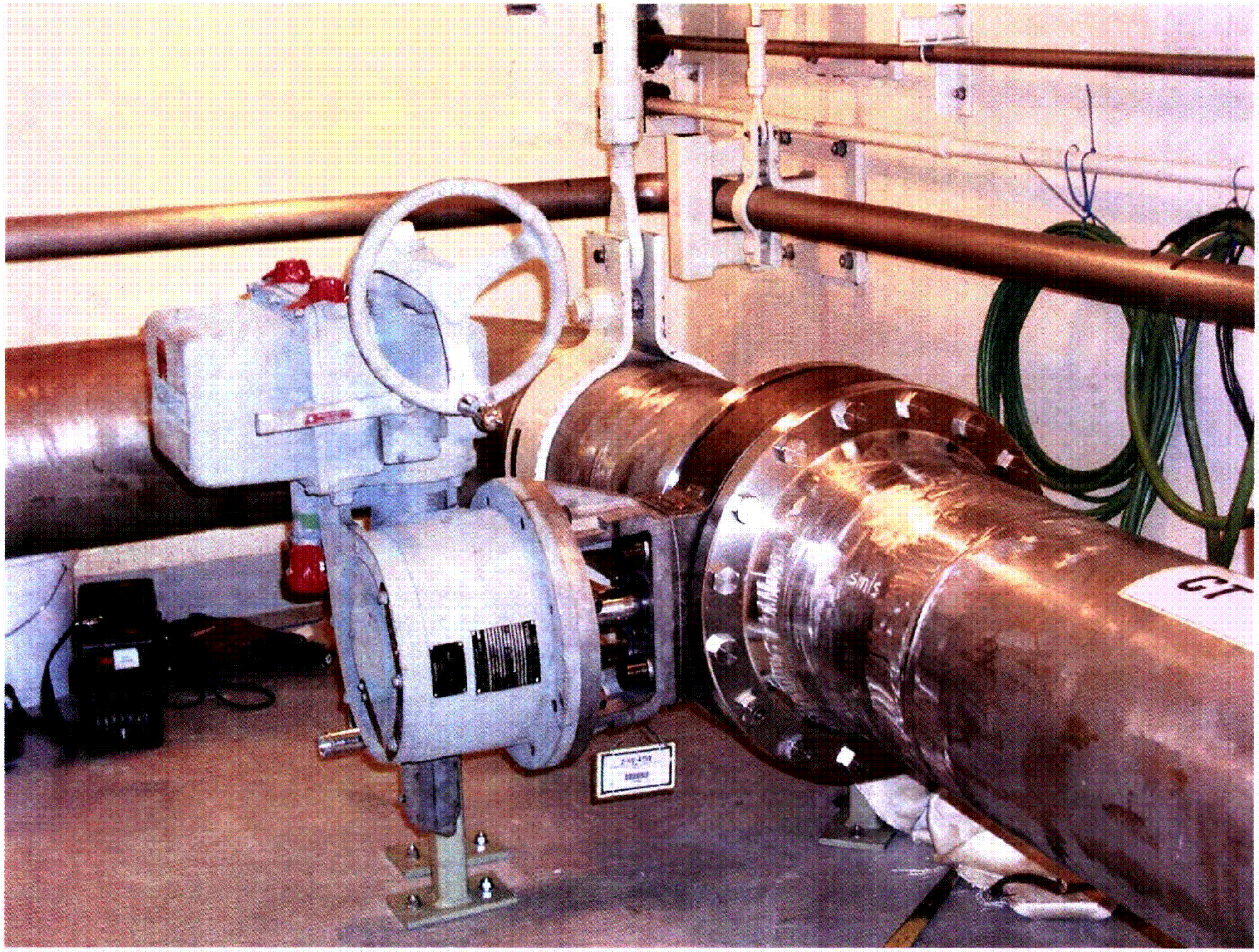
# P-3.j.2-1 Shop Assembly



# P-3.j.2-2 New Sump Strainer

# P-3.j.2-3 New Sump Strainer

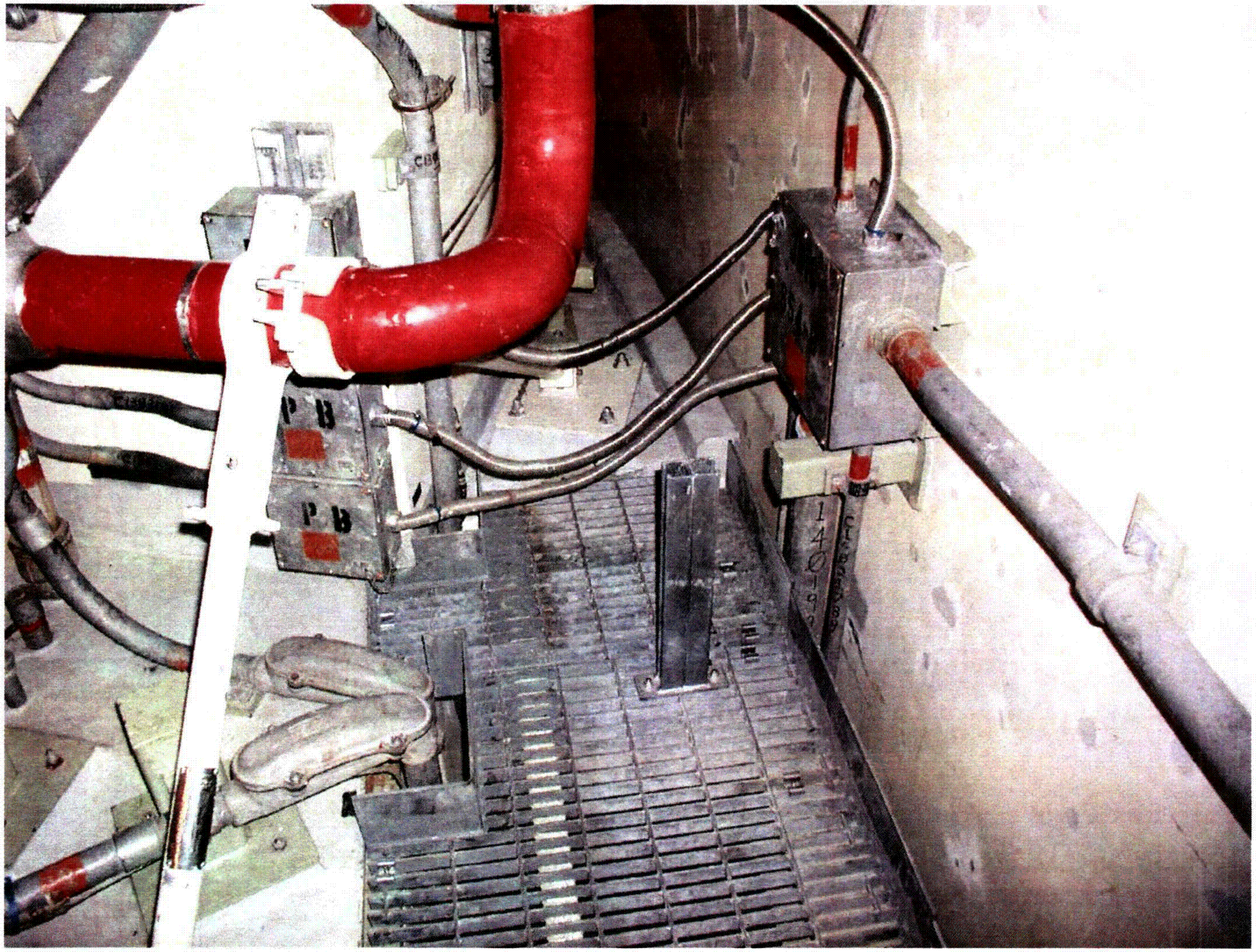
# P-3.j.2-4 New Sump Strainer



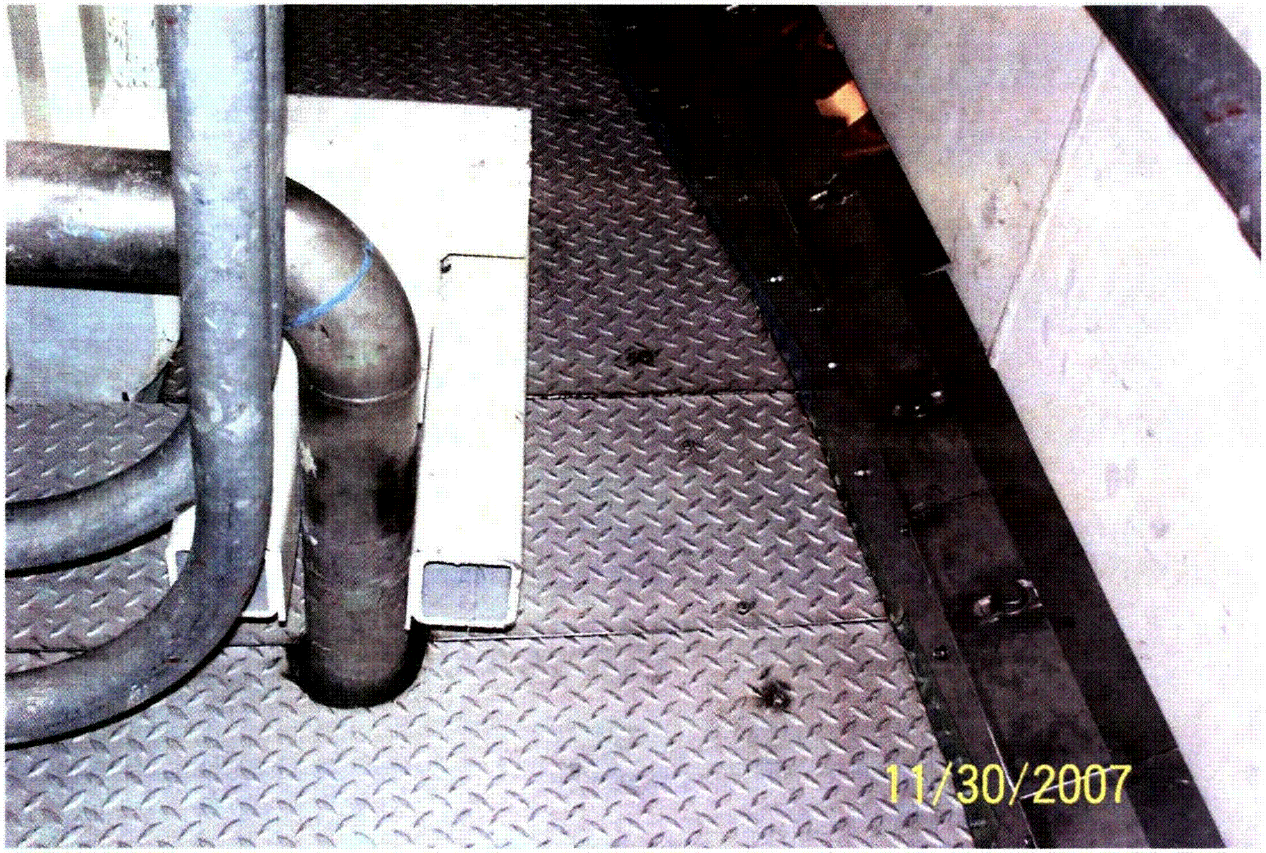

# P-3.J.3-1 MOV Modification


# P-3.J.3-2 Equipment Drain Capped


# P-3.J.3-3 Normal sump drain cover

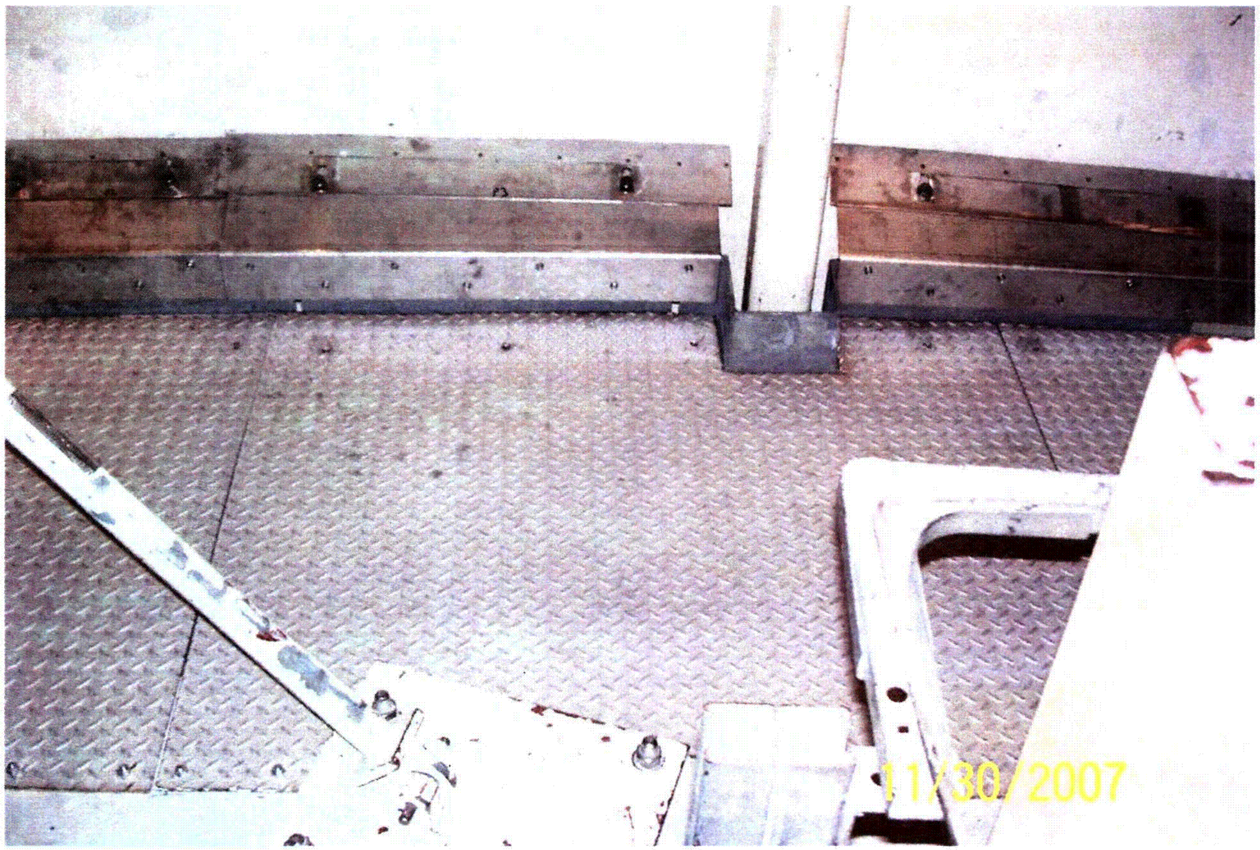


# P-3.J.3-4 El. 832 Grating and Gap



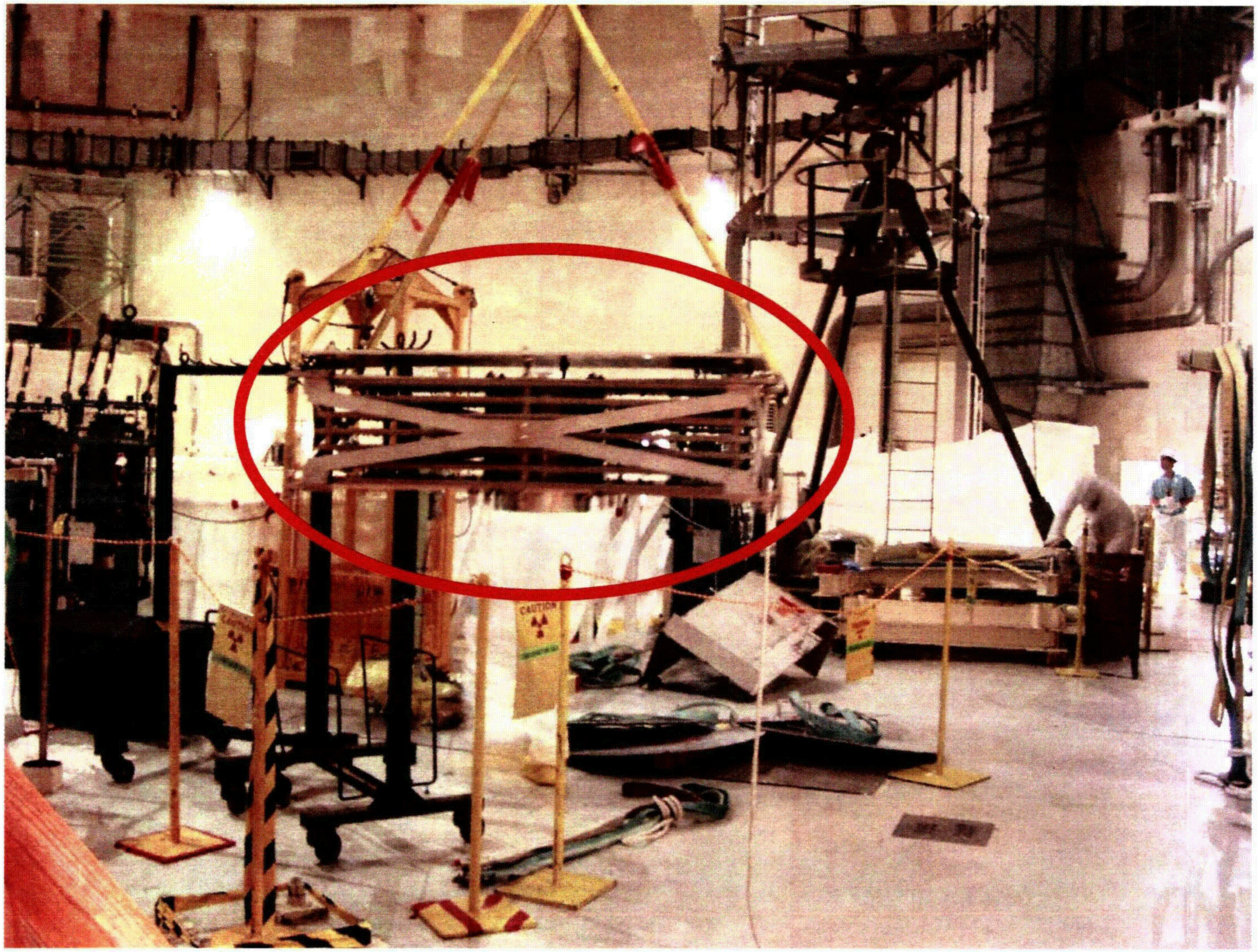

# P-3.J.3-5 Flashing Mod


# P-3.J.3-6 Flashing Mod



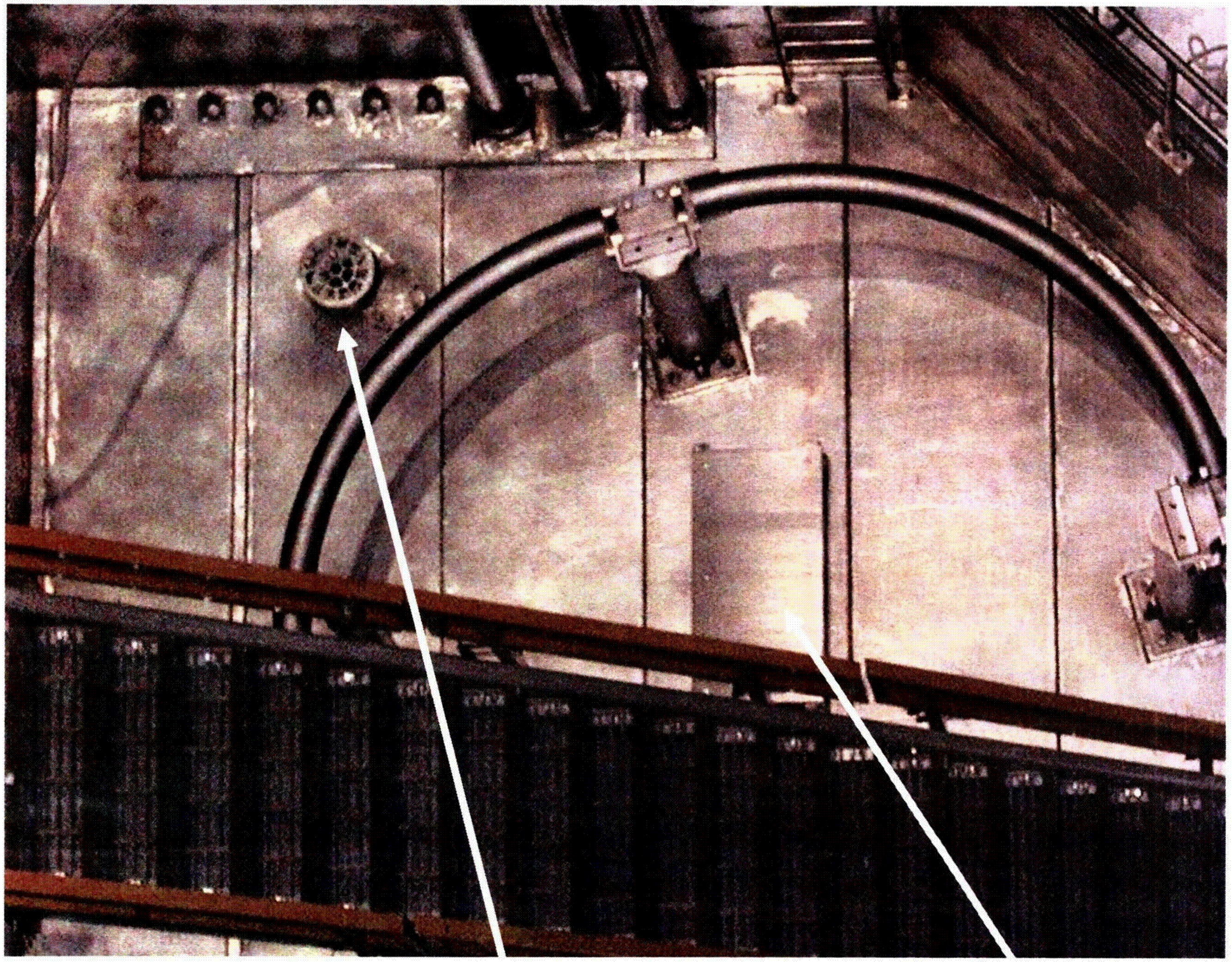

# P-3.J.3-7 Flashing Mod


# P-3.J.3-8 Diverter Modification

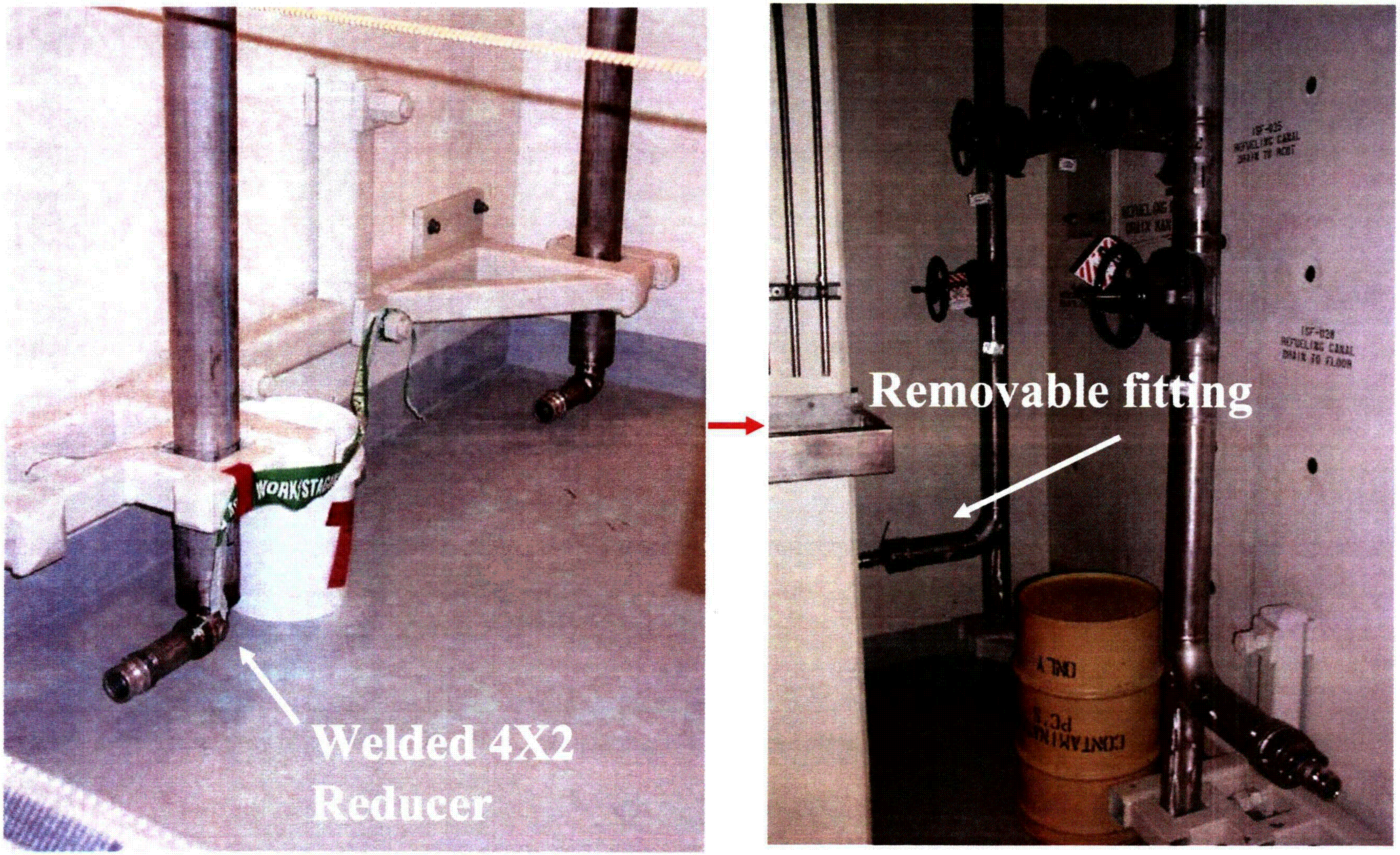


**P-3.I.2-1 Drain Strainer**

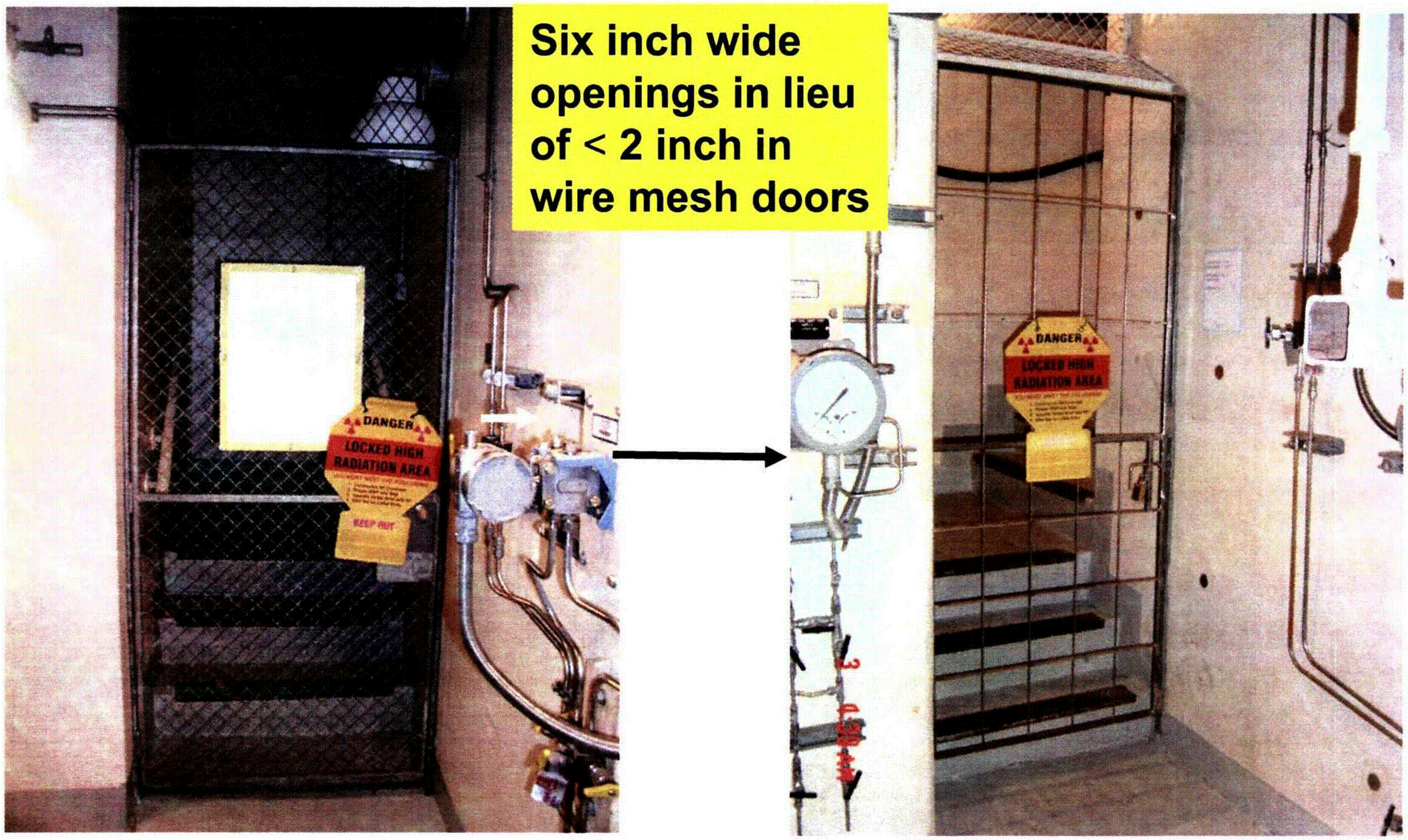
# P-3.I.2-2 Six Inch Drain Debris Screen



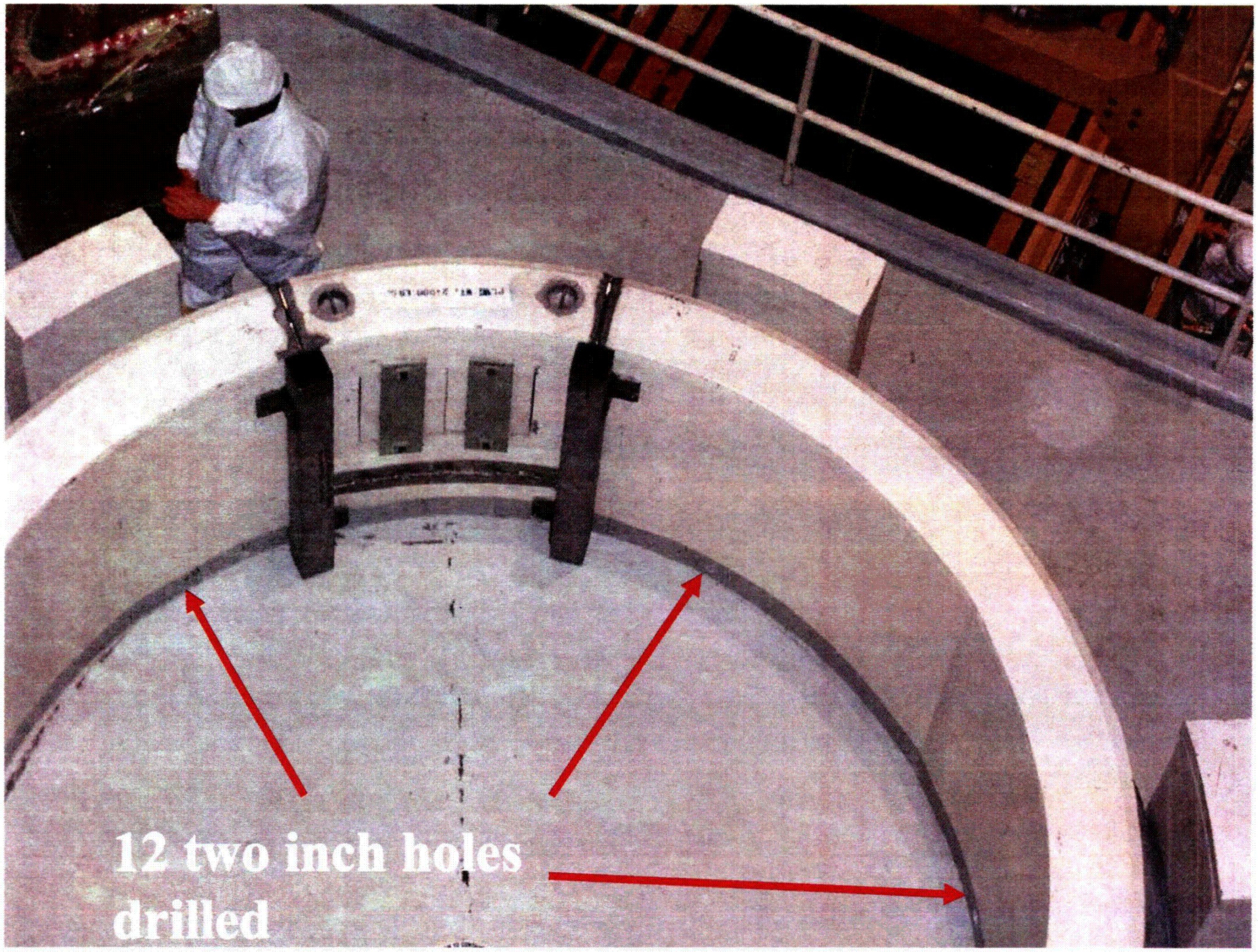
# P-3.I.2-3 Debris Screen and Drain Strainer



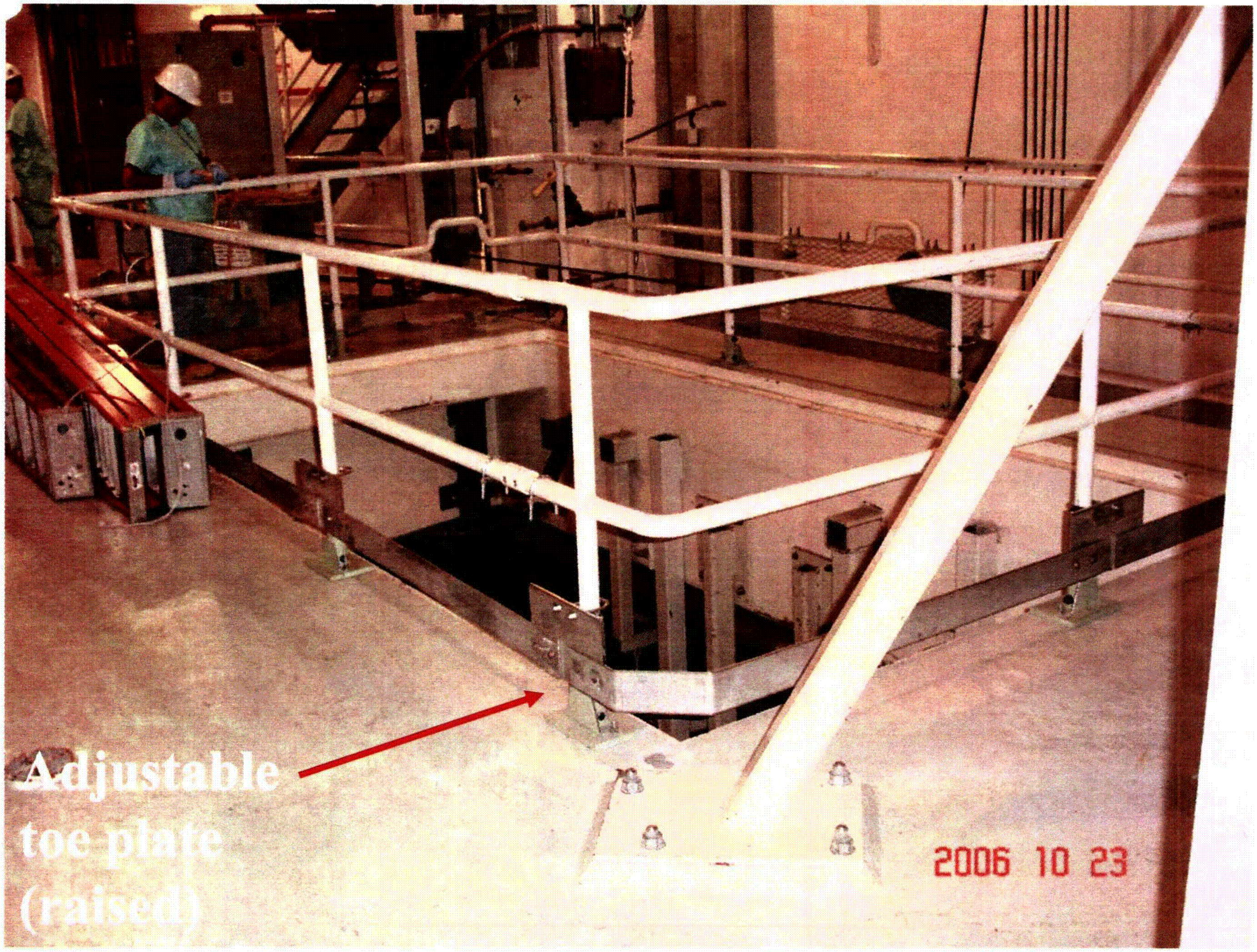

# P-3.I.2-4 Drain Modification



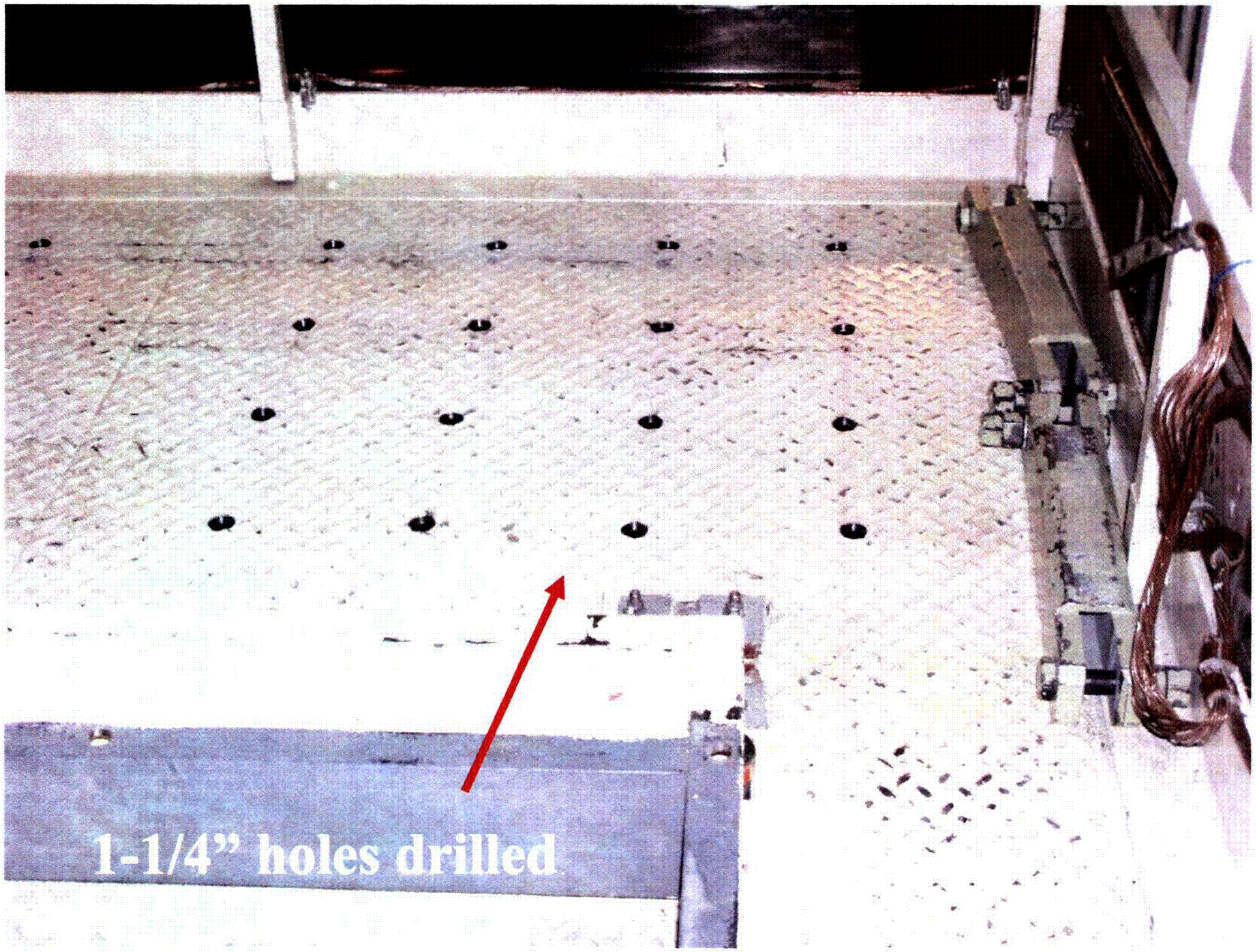

# P-3.I.3-1 Wire Mesh Door Mod



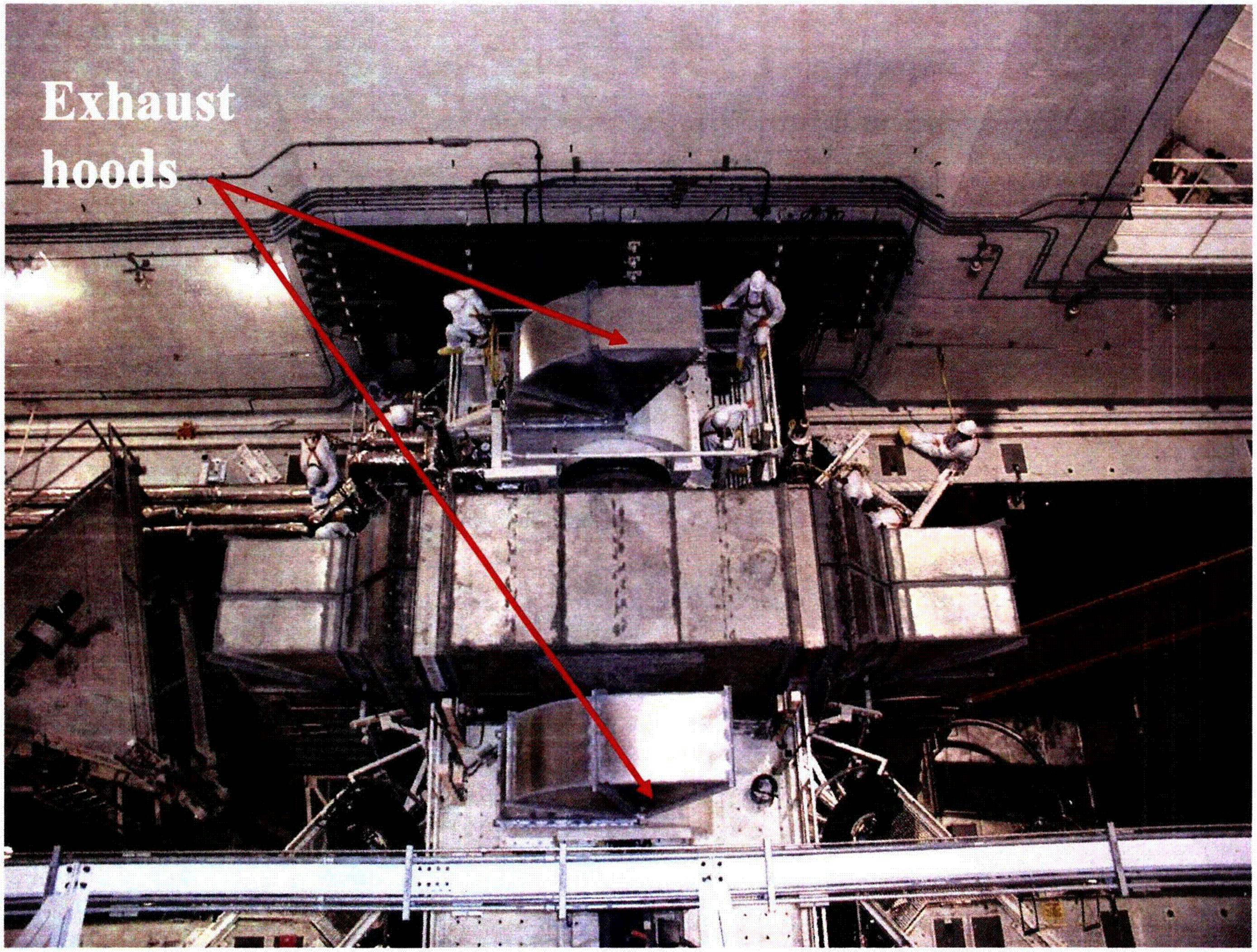

**P-3.I.3-2 Shield Wall Modification**



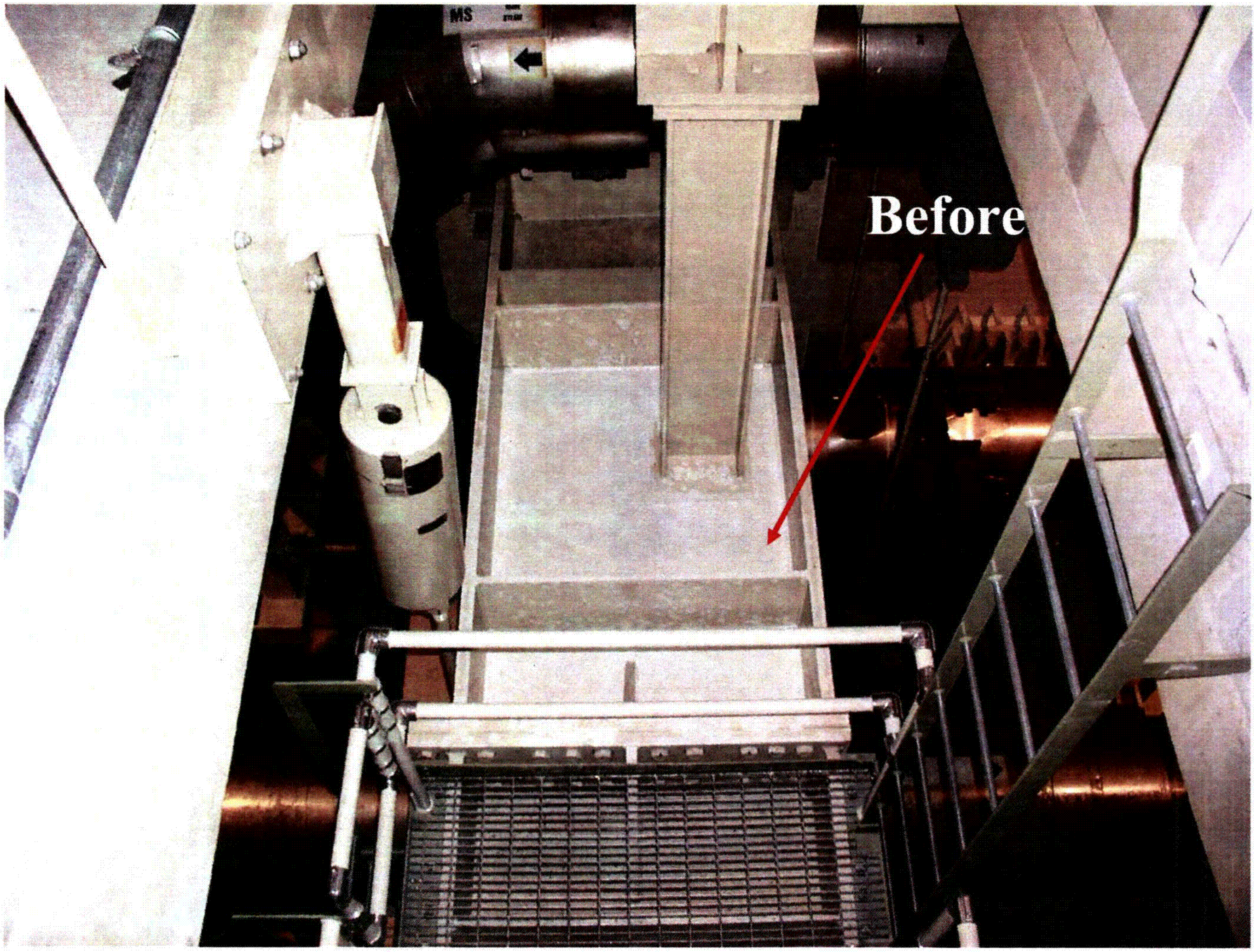

# P-3.I.3-3 Toe Plate Modification



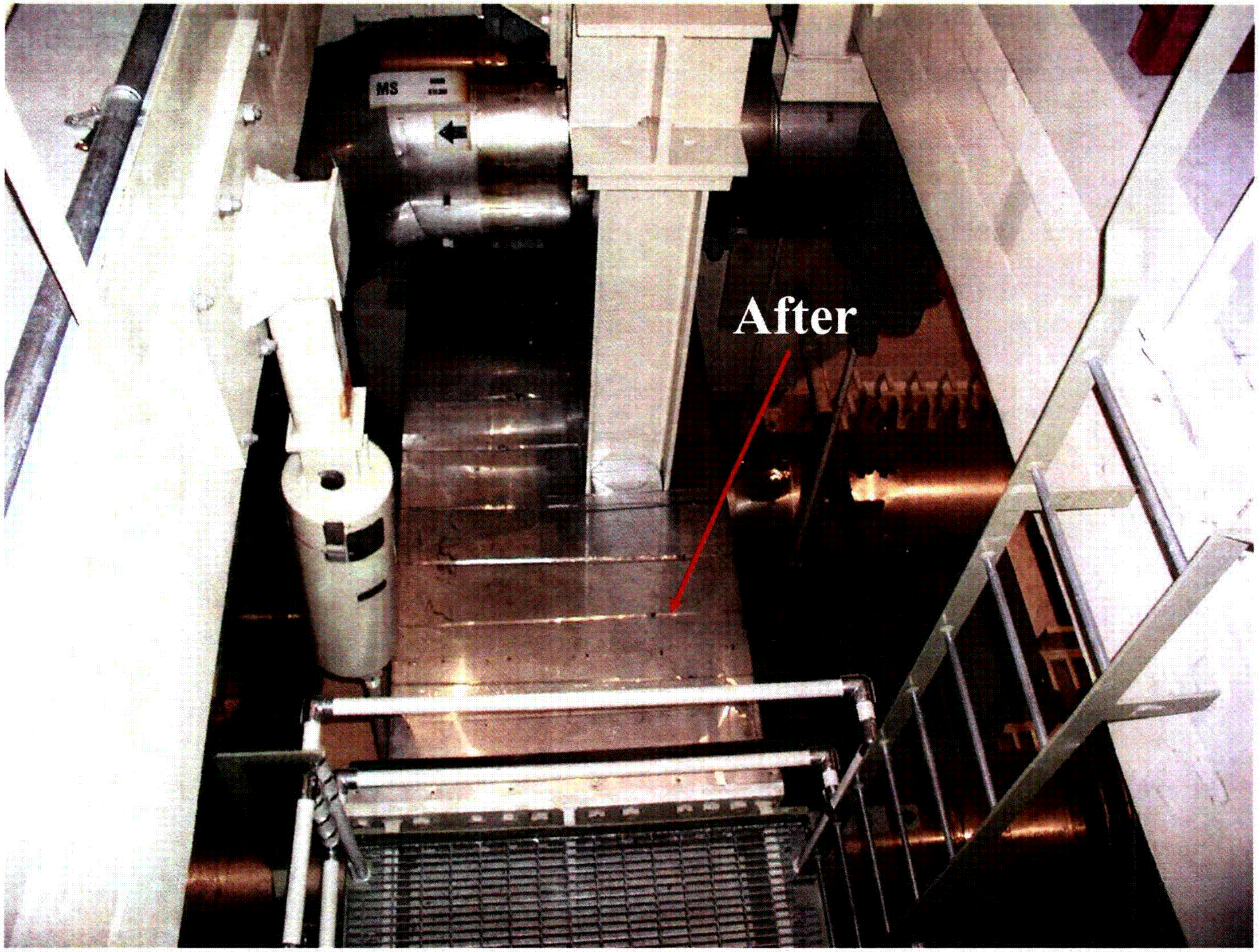

# P-3.I.3-4 Platform Modification



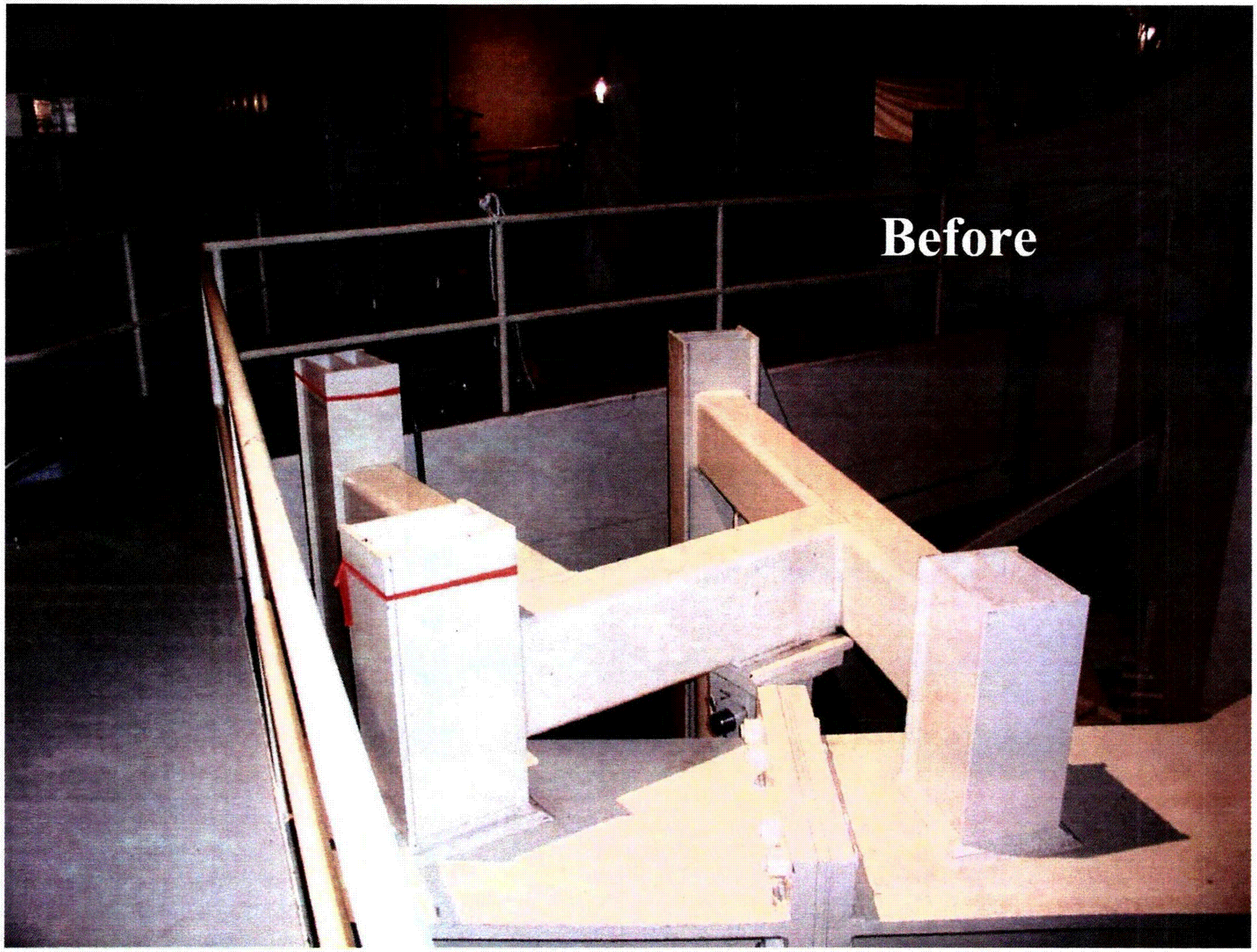

# P-3.I.3-5 Ventilation Exhaust Modification



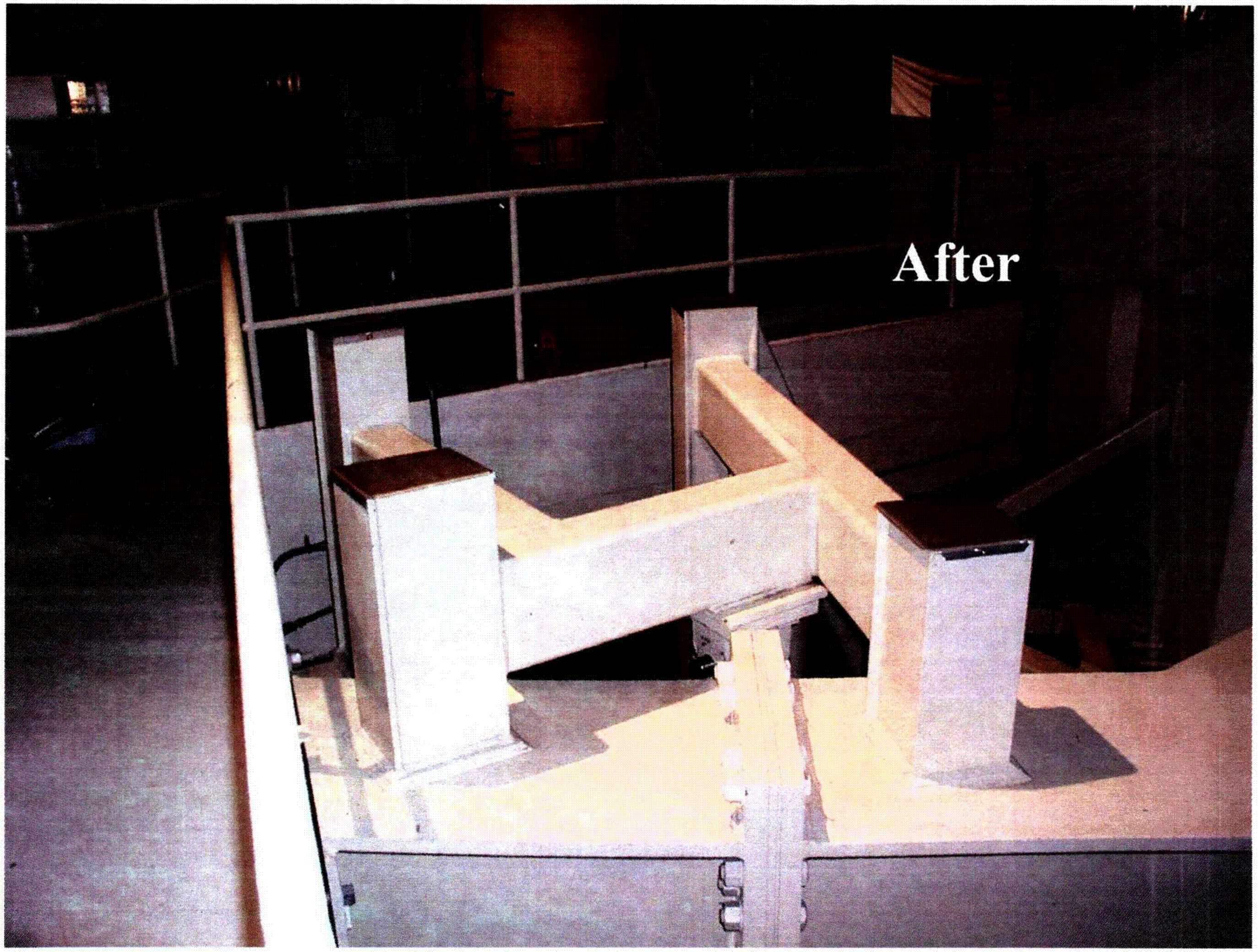

# P-3.I.3-6 Whip Restraint




# P-3.I.3-7 Whip Restraint Flashing




# P-3.I.3-8 Box Beams




# P-3.I.3-9 Newel Caps