ATTACHMENT 2

AREVA

ANP-10293
Revision 0

# U.S. EPR Design Features to Address GSI-191
Technical Report

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Non-Proprietary

## Nature of Changes

| Item | Section(s) or Page(s) | Description and Justification |
|---|---|---|

## Contents

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## Nomenclature

| Acronym | Definition |
|---|---|
| ALDEN | Alden Research Laboratory |
| BWR | Boiling Water Reactor |
| CSS | Containment Spray Systems |
| ECCS | Emergency Core Cooling System |
| FME | Foreign Material Exclusion |
| FPPS | Fuel Pool Purification System |
| GL | Generic Letter |
| GSI | Generic Safety Issue |
| HELB | High Energy Line Break |
| ILCO | Instrumentation Lances Storage Compartment |
| IRWST | In-Containment Refueling Water Storage Tank |
| LBLOCA | Large Break Loss of Coolant Accident |
| LHSI | Low Head Safety Injection |
| LOCA | Loss Of Coolant Accident |
| LWR | Light Water Reactor |
| MHSI | Medium Head Safety Injection |
| NPSH | Net Positive Suction Head |
| PWR | Pressurized Water Reactor |
| RCS | Reactor Coolant System |
| RG | Regulatory Guide |
| RMI | Reflective Metal Insulation |
| TSP | Tri-Sodium Phosphate |
| ZOI | Zone Of Influence |

# 1.0 INTRODUCTION

This report describes the U.S. EPR design with respect to Generic Safety Issue (GSI) - 191. GSI-191 is concerned with the potential for post-accident debris blockage that could interfere with the capability of the recirculation mode of the emergency core cooling system (ECCS) during long-term reactor core cooling. NRC Regulatory Guide (RG) 1.82 (Reference [1]) describes acceptable methods and guidelines for evaluating the adequacy of plant design features and ECCS performance, including a framework for licensees to develop, demonstrate, and implement a comprehensive resolution to GSI-191. This report assesses the U.S. EPR design with respect to RG 1.82 and the related generic letter (GL), GL 2004-02 (Reference [3].

Specifically, this report:

1. Describes the design features of the U.S. EPR that limit the impact of post-accident debris accumulation on ECCS sump performance.
2. Presents the supporting bases for the U.S. EPR design relative to GSI-191.
3. Presents an overview of related regulations and guidance.
4. Provides a review of RG 1.82 and GL 2004-02 conformance status.

The U.S. EPR sump design is robust with respect to post-accident debris accumulation and ECCS recirculation sump strainer blockage because of the following features:

1. The U.S. EPR will have limited post-accident debris relative to current light water reactors (LWR). Reactor coolant system (RCS) piping and components will be insulated with reflective metal insulation (RMI) where clearances permit. There will be little or no fibrous or micro-porous insulation and no calcium-silicate insulation used on the RCS.

2. The three-tiered debris retention design of the U.S. EPR ECCS recirculation system, comprised of the safety injection system (SIS) and the in-containment refueling water storage tank (IRWST), is an effective solution to post-accident ECCS pump strainer clogging. The combination of weirs, trash racks and retaining baskets are effective in retaining most of the debris. As a result, very little debris will reach the ECCS strainers. The ECCS strainers have large screen surface areas to accommodate the small amount of debris that will reach them.

The U.S. EPR design conforms to the applicable RG 1.82 requirements as detailed in Table A-1 of Appendix A.

The features of the U.S. EPR that mitigate the risk of post-accident debris clogging the ECCS strainers are:

- A general layout of the plant that reduces the zone of influence (ZOI).
- The absence of a containment spray system (CSS) for design basis accident mitigation that would contribute to debris transport.
- Judicious selection of insulating materials.
- Multiple barriers that significantly limit the amount of post-accident debris reaching the ECCS strainers:
  - Weirs around the heavy floor openings that promote settling of debris on the RCS loop area floor.
  - Trash racks above the heavy floor openings to prevent large debris from being transported to the IRWST.
  - Retaining baskets below the heavy floor openings that capture the remaining debris contained in weir overflow.
  - Large volume and large area IRWST that results in relatively low flow velocities, which permits settling of the debris.

- Large surface area ECCS strainers with small screen mesh sized to minimize debris bypass that may potentially affect any downstream clogging of fuel or critical equipment. Strainer sizing is based on conservative assumptions.

The U.S. EPR sump system design has been validated by a comprehensive testing program which demonstrated:

- Effectiveness of weir/trash rack system.
- Retention capacity and effectiveness of the retaining baskets.
- Strainer retention capacity and large margins relative to the head losses across the strainers, for a given volume of debris.

In summary, this report concludes that the U.S. EPR reactor design provides an innovative and comprehensive solution to post-accident debris blockage that addresses the concerns of GSI-191. The U.S. EPR design conforms to RG 1.82 as detailed in Table A-1 of Appendix A.

# 2.0 U.S. EPR DESIGN FEATURES

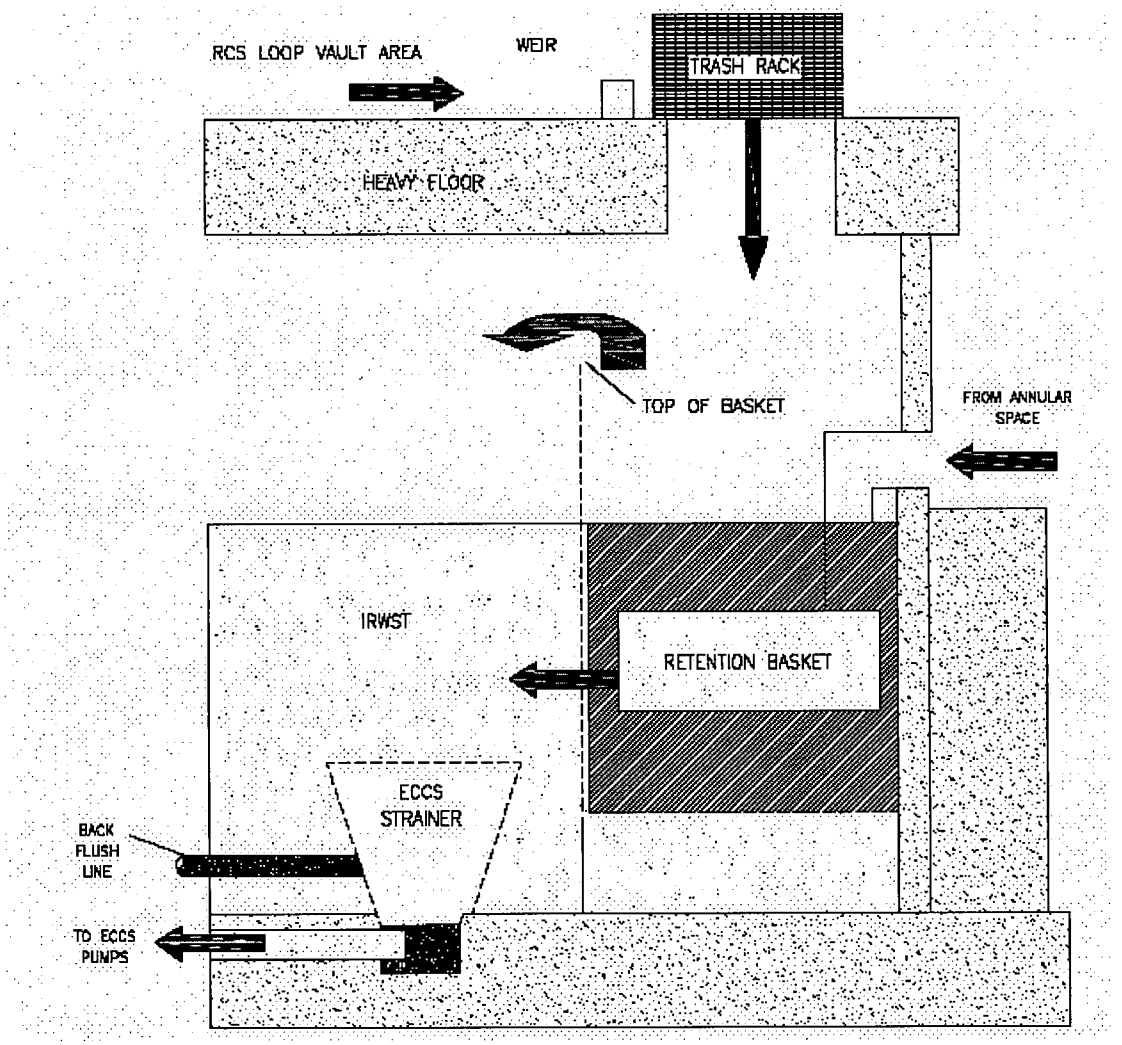
## *2.1 IRWST*

A key feature of the U.S. EPR design important to resolving post-accident debris blockage is the IRWST. The IRWST is functionally equivalent to the external refueling water storage tank found in the current fleet of PWRs. The IRWST contains a large volume of borated water that is monitored for a homogeneous concentration, level, and temperature. The IRWST serves as a water source, heat sink, and return reservoir for ECCS. The IRWST is an open pool within a partly immersed building structure. The walls of the IRWST have an austenitic stainless steel liner covering the immersed region of the building structure. The liner prevents interaction of the boric acid and concrete structure and provides water tightness. Locating the IRWST inside containment and immediately below the RCS loop vaults permits integrating design features that collectively represent an effective solution for preventing post-accident debris blockage and ECCS sump clogging.

## *2.2 Defense-in-Depth Strategy*

The U.S. EPR design takes advantage of the in-containment physical arrangement to develop a tiered "defense-in-depth" strategy against ECCS sump suction clogging as shown in Figure 2-1. The return water discharged from a loss of coolant accident (LOCA) drains to the containment heavy floor and flows to the IRWST.

**Figure 2-1 U.S. EPR ECCS Sump Blockage Mitigation Design Features**




This tiered "defense-in-depth" strategy includes:

- A large area, low flow velocity region in each of the four RCS loop vaults that promotes debris settling.
- A set of four protective weir/trash rack structures to retain large debris in the RCS loop vault.
  - The weir (curb) is approximately 2 inches high, to facilitate water pooling and debris settling in the RCS loop vault areas.

- The trash rack is a 4x4 inch heavy-duty screen that fully encompasses the floor opening and prevents large debris from entering the retaining basket below.

- Four retaining baskets in the IRWST. Each retaining basket is located under each weir/trash rack port to catch and retain any small debris that is carried through the trash racks by ECCS recirculation flow.
- Large area, low flow velocity region within the IRWST promotes settling of fine debris that passes through the retaining baskets.
- Four large surface area three-dimensional flat screen sump strainers in the IRWST, each protecting one of the four ECCS pump suction sumps located in the floor of the IRWST.

Additional features associated with these barriers that contribute to the overall effectiveness of the system include:

- Retaining basket area sized to overlap trash rack portal area so that ECCS recirculation flow falls within the retaining basket.
- An approximately 1.6 ft gap between the top of the retaining basket and the bottom heavy floor permits the retaining basket to overflow into the IRWST should the retaining basket be filled with debris.
- Retaining basket screen mesh size is equivalent to the strainer screen mesh size; both are sized to minimize fine debris that may bypass the strainer and obstruct downstream clearances in the ECCS flow path (including flow through the core).
- Inverted side screens on the sump suction strainers to promote gravitational release of debris beds in low flow or no flow conditions.
- Retaining baskets and ECCS strainers sized so that each set is sufficient to accommodate the anticipated debris load resulting from the worst-case LOCA.

- RCS insulation materials selected to minimize the quantity of insulation debris known to be highly deleterious to post-LOCA ECCS function.

## *2.3 Details of the U.S. EPR ECCS Sump Blockage Mitigation Design Features*

Figures 2-2, 2-3, and 2-4 show the locations of the weir/trash rack structures, the retaining baskets, and the sump strainers in relation to the RCS and the IRWST. Figures 2-5 and 2-6, respectively, show the design of the trash rack structure and the sump strainer structure.

**Figure 2-2 Elevation View of ECCS Sump Blockage Mitigation Features**

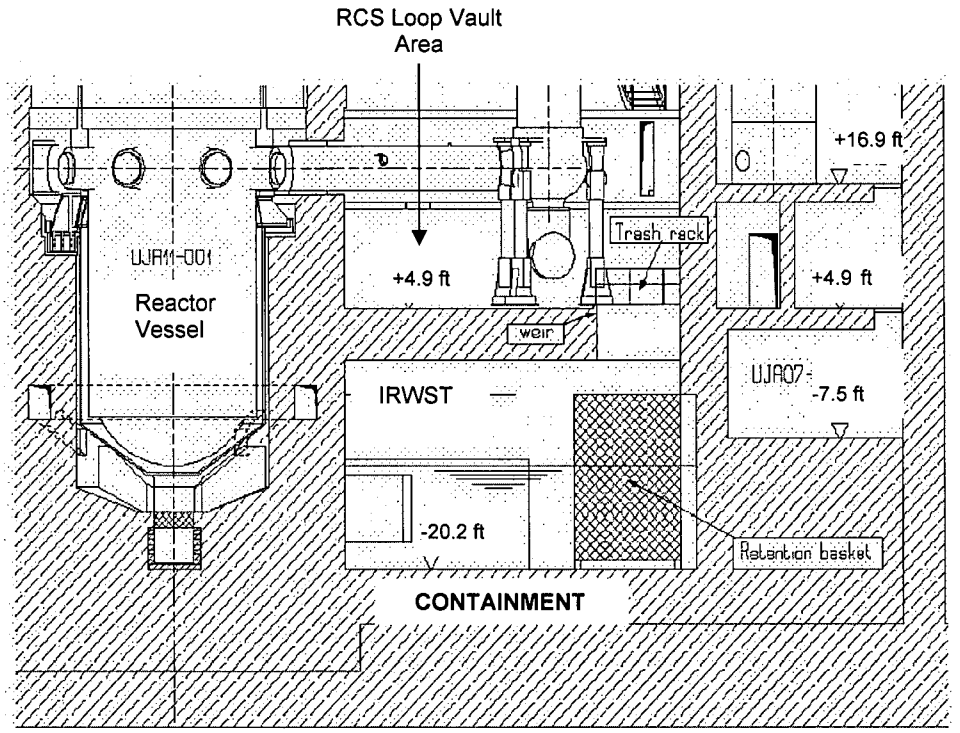


**Figure 2-3 IRWST Cut-away View**

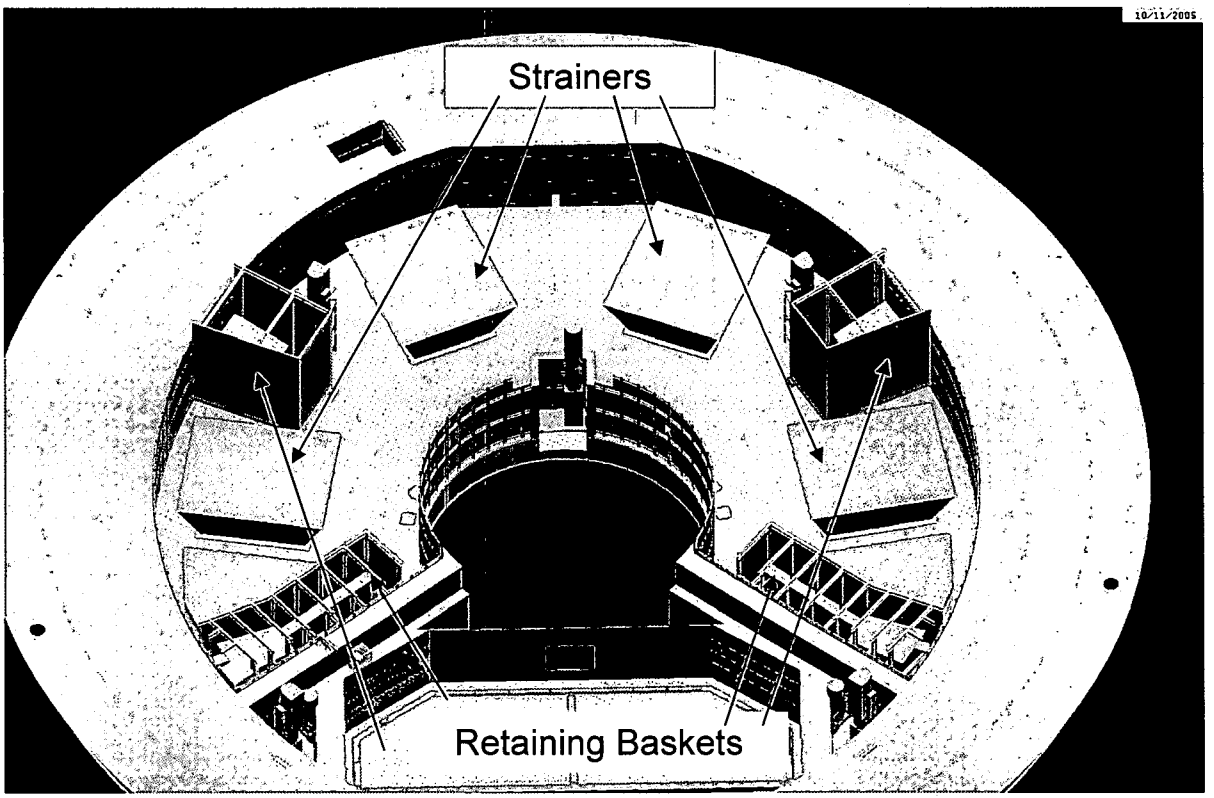


**Figure 2-4 Weir and Trash Rack Locations Above the Heavy Floor**

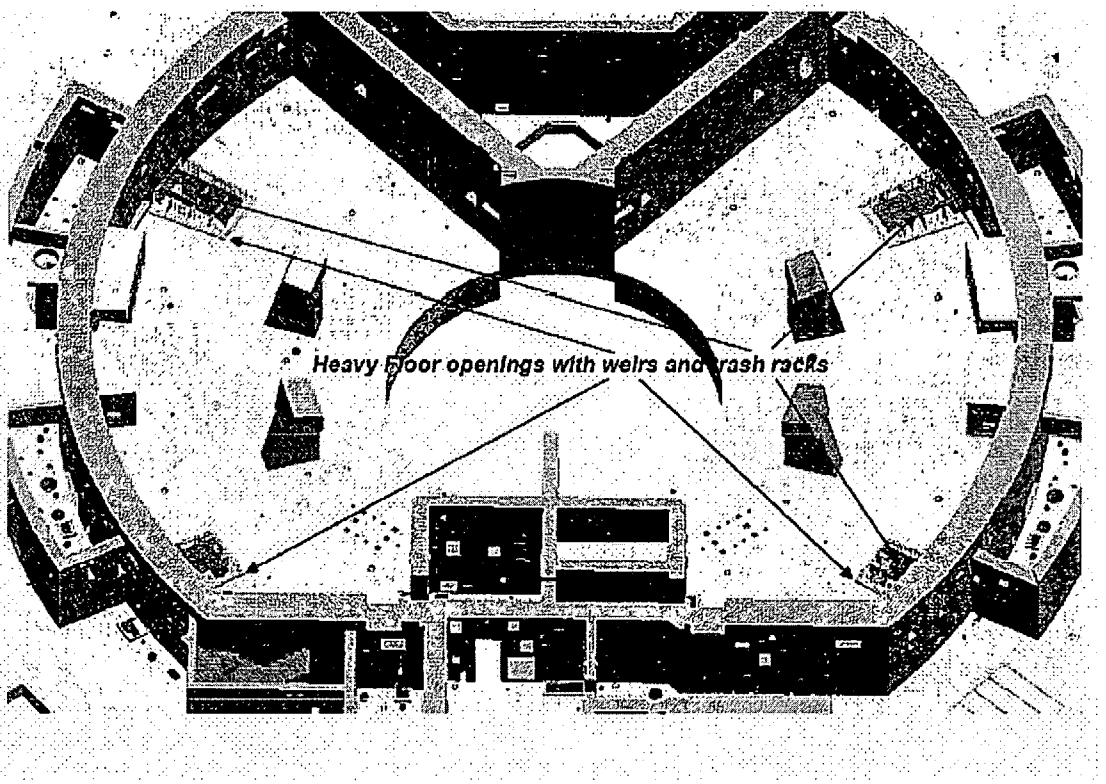



**Figure 2-5 ECCS Trash Rack Structure (typical of 4)**

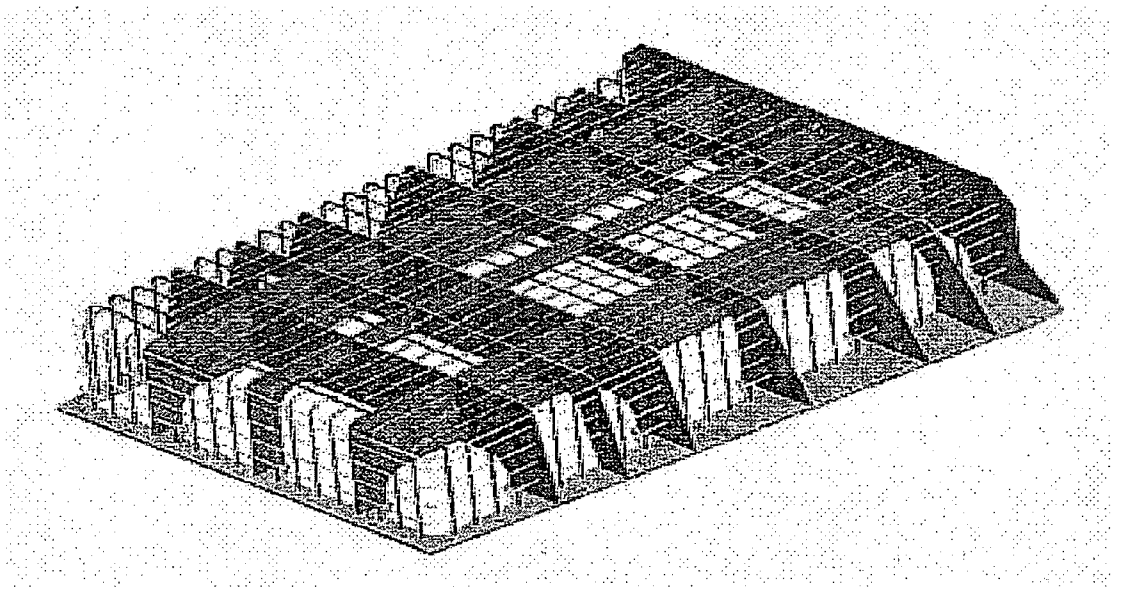
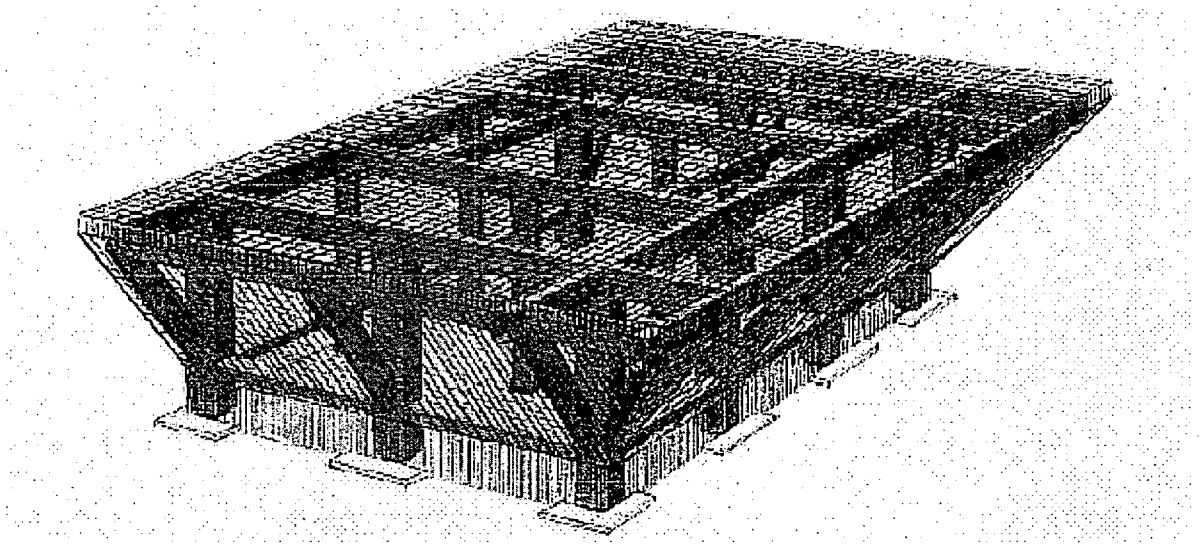


**Figure 2-6 ECCS Sump Strainer Structure (typical of 4)**



### *2.3.1 Weirs and Trash Racks*

There are four openings in the RCS loop area "heavy" floor that open to the IRWST below. Each opening is approximately 50 $ft^2$ in area and is protected by a weir and trash rack assembly. The weir is a 2-inch high concrete curb around the perimeter of the floor opening that permits pooling of LOCA return water and promotes debris settling in the RCS loop vault area. The trash rack is a box-like mesh structure approximately 22 inches tall that consists of a 4x4 inch rigid metal grid that envelopes the floor opening. Each of the floor openings is aligned with the retaining basket located below. In addition to the protection offered by the trash racks, the 6.6 ft depth of the floor openings also provides jet impingement protection by limiting the angle of any jet that could pass through the opening unimpeded.

The weirs and trash racks prevent most of the LOCA-generated debris from passing through the four heavy floor openings to the IRWST below. LOCA-generated debris that passes through each trash rack will fall into a retaining basket.

### *2.3.2 Retaining Baskets*

A retaining basket is positioned under each of the four heavy floor openings. The retaining baskets collect and retain debris that pass through the trash racks. The retaining baskets are constructed of austenitic stainless steel. The mesh size of the retaining baskets (nominal opening 0.08 x 0.08 inches) is the same size as the down stream ECCS sump strainer mesh size.

The perimeter of the upper portion of the retaining basket extends approximately 1.5 ft beyond the perimeter of the heavy floor opening. This extension prevents debris that passes through the trash racks from bypassing the retaining basket and reaching the sump strainers. There is a gap of approximately 1.6 ft between the top of each basket and the heavy floor to provide a flow path for return water in the event the basket becomes filled with debris.

The volume of each retaining basket can accommodate the debris generated from the limiting break. Water level in the basket is self-regulating and increases as the lower portion of the basket becomes filled with debris. Water overflow over the top of the retaining basket would occur after the debris have been captured.

Two of the four retaining baskets are split into two compartments: a large one (volume of approximately 1766 $ft^3$) dedicated to the flow from the heavy floor, a smaller one (volume of approximately 530 $ft^3$) dedicated to the flow from the annular space. The latter compartment is lower and its height is designed to minimize water retention in the annular space. The volume of the two other baskets is approximately 3000 $ft^3$. Each retaining basket has approximately 721 $ft^2$ of screen surface area for filtering out debris.

### *2.3.3 IRWST (ECCS) Sump Strainers*

The ECCS sump strainers are arranged above each of their respective sumps. The following aspects are taken into account to size the IRWST strainers:

- Nature of the debris (e.g., fiber, RMI, particulates, paint chips).
- Maximum quantity of debris that might reach one strainer during the recirculation phase after a large break loss of coolant accident (LBLOCA) (based on conservative assumptions for the localization of the break, quantity of debris produced, quantity of debris carried to the strainers, flow paths to the IRWST).
- Head loss correlations for the considered debris as a function of the thickness of the debris bed on the strainer (e.g., evaluation of the clogged strainer pressure drop, evaluation of the strainer minimal area with regard to the pumps net positive suction head [NPSH] requirements, calculation of the debris retained in the retaining basket and resulting strainer minimum area).

A bounding approach is used for sizing the ECCS strainers. Based on conservative assumptions, the minimal design surface area for an ECCS strainer is approximately 690 $ft^2$. The installed strainer will have about 10% more surface area (approximately 760 $ft^2$) to provide additional margin.

The screen filters retain debris to prevent pump/equipment malfunction and clogging of the smallest restrictions in the core. The screen design reflects a flat grid configuration with a nominal opening size of 0.08 x 0.08 inches to limit passage of debris through the strainer.

Validation tests using representative debris demonstrated conservative margins for the dimensioning of the strainers. Because most of the debris are trapped in the retaining basket, a limited amount of debris will reach the ECCS strainers. The small amount of debris reaching the strainer results in a very small head loss through the strainer.

## 2.4 ECCS Strainer Back-flush System

The U.S. EPR design provides an ECCS strainer back-flush system. However, credit is not taken for this system for continued ECCS operation during post LOCA recirculation.

The strainer back-flushing tests demonstrated that efficient back-flushing can be obtained using water from the instrumentation lances storage compartment (ILCO). The ILCO elevation and the supply line diameter provide sufficient head and flow to efficiently back-flush the ECCS strainers.

Use of the back-flush system is not relied upon to address the concerns of GSI-191. The tiered, defense-in-depth approach of the design is sufficient without the use of a back-flush system. The ECCS back-flush system is a Seismic Category II, non-safety-related system.

## 2.5 RCS Insulation

The judicious selection of insulating materials for piping and equipment inside containment is important in limiting post-accident debris. The U.S. EPR design approach is to extensively use RMI for the RCS piping and major components, including the reactor vessel, the steam generators, reactor coolant pump casings, and the hot, cold, and crossover legs. Jet impact-resistant, cassette-type encapsulated mineral wool insulation is used in locations not suitable for RMI. The use of fibrous and particulate-generating insulation materials (e.g., micro-porous insulation) is limited, and no calcium-silicate insulation is used on the RCS.

# 3.0 APPLICABLE U.S. EPR DESIGN BASES

The design of the U.S. EPR ECCS recirculation system coupled with the judicious selection of and control of insulating materials and other debris generating material effectively resolves the strainer clogging issue. This conclusion is based on a design that combines conservatism in estimating the strainer head loss caused by debris accumulation with a physical layout that sequentially prevents debris from reaching the ECCS sump strainers, and is substantiated by physical testing that demonstrated the overall system effectiveness.

Several serial processes were reviewed to quantify the amount of debris generated after a LOCA that could potentially clog the strainers and increase the pressure drop across the strainer:

1. The amount of material dislodged from the limiting ZOI (L/D of 7) was conservatively estimated by neglecting the protective features provided by compartmentalized components.

2. It was assumed that all dislodged material is transported to the IRWST and that all of this material is deposited on the strainer of one ECCS train.

The design is such that in this postulated event, the collected debris will not cause a loss of NPSH for the ECCS pumps. These assumptions form the underlying technical basis for the U.S. EPR strainer design.

Results of the AREVA IRWST strainer testing program validate the design of the U.S. EPR ECCS recirculation system.

## *3.1 Technical Basis for the ECCS Sump Recirculation Design Features*

The technical basis for the ECCS sump recirculation design features is provided by AREVA studies, as summarized below. The results of these studies demonstrate the

effectiveness of the sump recirculation design features. Furthermore, select features of the U.S. EPR design (e.g., extensive use of RMI) promote enhanced system reliability.

The sizing of the ECCS strainers and the assessment of available NPSH for the LHSI and MHSI pumps are discussed below. An assessment of vortex formation and potential air-ingestion and an assessment of effects downstream of the ECCS pumps are also provided.

### *3.1.1 ECCS Strainer Sizing*

The ECCS strainers and the IRWST debris retaining baskets are designed to collect all the debris that can reach the IRWST in the event of a LOCA. The following inputs were used to size the strainer:

- Maximum quantity of debris that might reach one strainer during the recirculation phase after a LBLOCA.
- Nature of the debris—Head loss correlations for the considered debris as a function of the thickness of the debris bed on the strainer.
- Maximum pressure losses acceptable regarding NPSH margin for the LHSI and MHSI pumps and the mechanical strength that the strainer can withstand.

#### *3.1.1.1 Debris Source Term*

The debris source term is based on the maximum volume of debris generated by the limiting break, which corresponds to the double-ended rupture of the hot leg at the entrance to the steam generator. Based on Reference [2], the debris are collected from a ZOI that corresponds to a sphere with a radius of 7 pipe diameters (approximately 23 ft) centered at the break location. The total debris source term is summarized in Table 3-1.

**Table 3-1 Total Debris Source**

| Material | Assumed for Evaluation | Estimated U.S. EPR Maximum |
|---|---|---|
| Mineral wool in cassettes | 880 $ft^3$ | 0 $ft^3$ |
| Mineral wool in fiber glass cloth and protected by stainless steel sheet | 140 $ft^3$ | 0 $ft^3$ |
| Mineral wool in mattress around auxiliary pipes protected by stainless steel sheet | 210 $ft^3$ | 0 $ft^3$ |
| RMI (primary reactor coolant pump) | 105 $ft^3$ | 1345 $ft^3$ |
| Paint chips | 110 lb | 110 lb |
| Latent debris | 110 lb | 110 lb |
| Microporous insulating material | 220 lb | 220 lb |

The assumptions for the amount of paint chip debris were based on feedback from operating facilities, taking into account U.S. EPR design specifications. Because of the density of paint chips, most of them will settle and will not be transported.

The amount of latent debris is dependent on the cleanliness practices of the plant operator. Based on operating experience and sampling performed on operating plants, a value of 110 lb was conservatively selected. Because of the large filtering area provided by the four retaining baskets and four ECCS strainers, a significant amount of latent debris would be required to impact screen head loss.

#### *3.1.1.2 Debris Transport Scenarios*

Two scenarios are considered:

- In the first scenario, no credit is taken for hold-up by the retaining baskets. Latent debris, paint chips and metal debris are assumed to settle out within the loop area or the IRWST. The balance of the total debris source term (1230 $ft^3$ of mineral wool from Table 3-1) is conservatively assumed to reach only one of the ECCS strainers.
- In the second scenario, credit is taken for debris hold up in the retaining basket. In this case the retaining basket is assumed to be full to its top level 6.6 ft above the IRWST water level. In this condition, it is estimated that 597 $ft^3$ of mineral wool will be retained by the basket. This results in 633 $ft^3$ of mineral wool reaching the ECCS strainer.

#### *3.1.1.3 ECCS Strainer Head Loss*

The ECCS strainers are mechanically designed to accommodate a 6.6 ft pressure differential. For strainer pressure drop, a maximal flow rate of approximately 3960 gpm is assumed that corresponds to the combined LHSI and MHSI pump design flow rates in Table 3-2.

For the first scenario (i.e., no credit for retaining baskets), a debris loading of 1230 $ft^3$ was uniformly loaded on the strainer with a pressure differential of 4.9 ft of water, the resulting required strainer surface area is 700 $ft^2$. In the second scenario, 633 $ft^3$ of mineral wool debris is assumed to be uniformly loaded on the strainer; however, for conservatism, a factor of 2 was applied. The resulting surface area for the strainer was 721 $ft^2$. The as-designed strainer will have a surface area of 753 $ft^2$, which provides additional margin.

Even without crediting debris hold-up by the retaining baskets, the installed strainer has sufficient area to accommodate the maximum amount of debris and still operate within

its design envelope. The proposed strainer will operate with significant design margins because of:

- Debris hold-up by the retaining baskets.
- The extensive use of RMI in lieu of mineral wool.

#### *3.1.1.4 NPSH Assessment*

An assessment has been performed of NPSH available to the LHSI and MHSI pumps following a LBLOCA. The results are summarized in Table 3-2.

**Table 3-2 NPSH Assessment**

| Parameter | LHSI Pump | MHSI Pump |
|---|---|---|
| Design Flow Rate, Q | 2860 gpm | 1100 gpm |
| Minimum NPSH required @ Q | ≈6.9 ft | ≈10.5 ft |
| Available NPSH, Clean filter | 12.1 ft | 15.4 ft |
| Available NPSH, (Assumes 2.3 ft head loss plus 1.6 ft for margin) | 8.2 ft | 11.5 ft |

As indicated in the above table, sufficient NPSH is available to the LHSI and MHSI pumps.

#### *3.1.1.5 Vortex/Air Ingestion Assessment*

The overall height of the ECCS strainer from the floor of the IRWST is approximately 5.2 ft. The post-LBLOCA water level in the IRWST is approximately 10 ft. Based on this information, the ECCS strainers will remain significantly submerged (by approximately 5 ft). In addition to the strainers, each sump has installed vortex suppression grids. These vortex suppression grids are arranged inside the sumps above the suction lines to prevent vortex formation. Because the presence of the vortex suppressors and the amount of submergence during operation prevents vortex formation and air-ingestion, damage to the ECCS pumps is precluded.

#### *3.1.1.6 Downstream Effects*

The design of the ECCS recirculation system minimizes the negative impact of debris clogging on components downstream of the strainers. The concern is the potential for damage to the ECCS pumps and for blockage of the fuel assembly inlet nozzles.

This potential is significantly reduced by the multiple barrier design of the ECC recirculation system:

1. The retaining basket screens and ECCS sump strainer screens are the same mesh size, 0.08 x 0.08 inches.

2. The fuel assembly inlet nozzles prevent passage of particulates 0.10 inches in size or larger.

Because most of the debris are captured in the retaining basket and then the balance by the strainers, the flow through the ECCS pumps and the core will not contain particulates of significant size. This is substantiated by the observation of a particulate level of 10 ppm or less in the water downstream of the ECCS strainer during IRWST strainer validation testing. Furthermore, downstream components (e.g., ECCS pumps) are designed to accommodate fluid with solid particles with dimensions of 0.08 x 0.08 inches or less. Therefore, downstream effects are expected to be minimal.

### *3.2 IRWST Strainer Validation Testing*

The U.S. EPR design incorporates features based on operating experience and AREVA design experience to prevent the detrimental effects of filter clogging due to post-accident debris generation.

These features consist of:

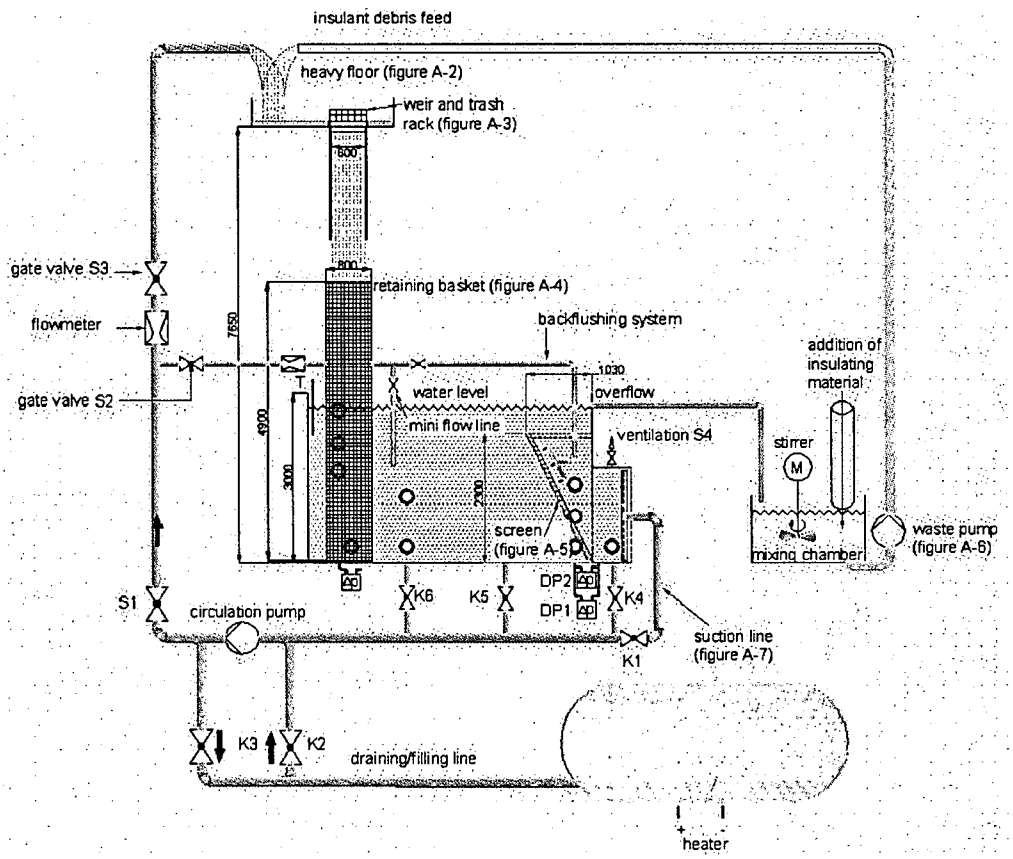
- Weir/trash racks on the heavy floor.
- Retaining baskets under the opening in the heavy floor.
- Sump strainers.

Testing has been performed and demonstrates margin against clogging effects. In summary, the test results showed that the U.S. EPR has a defense-in-depth design that significantly reduces the potential of ECCS sump clogging because wide margins to filter clogging were demonstrated even when important features of the design were not used in the testing.

### *3.2.1 Test Loop*

The test loop is shown in Figure 3-1.

**Figure 3-1 IRWST Strainer Validation Test Set-Up**




Note: Reference to figure designations and numerical values are immaterial to Figure 3-1.

The test loop is comprised of the following components and features:

- A basin 16.4 ft long, 9.8 ft high, 3.3 ft wide with a suction chamber attached to one end and a strainer (mesh size 0.11 x 0.11 inches, opening 0.08 x 0.08 inches, wire diameter 0.03 inches) separating the suction chamber from the basin.
- A recirculation pump.
- Piping with valves connecting the pump to the suction chamber and leading to the simulated break above the heavy floor and to a mini flow line injecting water directly into the basin.
- A simulation of part of the heavy floor with opening including removable weir and trash rack.
- A retaining basket with a screen area at the side facing the sump strainer with a mesh the same size as the suction strainer mesh.
- Instrumentation for measuring differential pressures, flow rates, and temperature.
- A system to inject the defined amount of debris consisting of mixing chamber with stirrer and a pumping unit.
- A back flushing system with spray nozzles in the suction chamber directed to the strainer.
- Debris addition equivalent to approximately 1/20 of the debris postulated for LBLOCA:
  - 6.2 $ft^3$ mineral wool.
  - Stainless steel jacket foils.
  - 5.5 lb paint chips (presumably not relevant for strainer head loss).
  - 5.5 lb latent debris.
  - 8.3 lb micro-porous insulating material.

### 3.2.2 Test Conditions

The tests were performed at a scale ratio of 1/20 for the design flow rate and for the surface area of the strainer, the retaining basket and the heavy floor opening. The test was performed at full vertical scale to provide a direct hydraulic correspondence between the test configuration and the full scale design.

While performing the tests, the following conservatisms were applied:

- Thoroughly aged mineral wool was employed in the tests. Part of the mineral wool would still contain binder even after many years of operation, which would reduce the amount of fine debris available for transport.
- The horizontal cross section of the retaining basket in the test was not optimized; so a small part of the debris coming down from the heavy floor was dropped outside the retaining basket, thereby increasing the amount of material transported to the sump screen.
- The floor area of the test tank was under-scaled relative to the IRWST; therefore, settling of debris and sedimentation was underestimated.
- The tests were performed at approximately 104°F; in a LOCA situation, the water temperatures for the first hours would be close to 212°F. The test runs with lower water temperatures will under estimate sedimentation.

### 3.2.3 Test Results

The strainer tests demonstrated the following:

- The weirs and the trash racks over the heavy floor openings retain a large part of the debris. Considering their large surface and the low flow velocity, they do not get clogged by the large debris. The larger debris settles around the opening but does not block the trash rack.
- The retaining basket has a very good retention ability. For the worst case conditions, the level in the retaining basket increased to 33 inches only, compared to an overflow level of 79 inches. Water falling from the heavy floor

induced significant turbulences in the upper 24 inches of the water in the retaining basket. The pressure fluctuations caused by this condition prevented built up of thicker layers of debris in the upper region of the screen and caused deposited material to slip or drop into deeper regions of the retaining basket. This indicates the retaining basket will only overflow in the unlikely event of it being completely filled by debris.

- For most tests with a retaining basket, the amount of debris passing the retaining basket was around 5% of the total amount of debris introduced in the test loop.
- A uniform debris bed was formed in all cases on the ECCS strainer. Considering the efficient behavior of the retaining basket, the amount of debris on the ECCS strainer was very limited, leading to head loss across the strainer of less than 0.15 psi compared to a design value of 2.2 psi at 104°F.
- Tests with the strainer alone without other filtering features shows that the head loss remains well below the design value even when the maximum amount of debris is introduced in the test loop.
- The particulate content of the water downstream of the strainer was 10 ppm at the beginning of the test and decreased to nonmeasurable values. This behavior is because of the fine mesh grids selected for the strainer and the retaining basket sieves and effectively eliminated downstream effects concerns.

Even with no credit taken for most of the conservative assumptions, the tests demonstrated the defense-in-depth concept against sump clogging:

- The retaining baskets have a retaining capability to prevent unacceptable downstream effects even when the sump screens do not function.
- The sump screens prevent unacceptable downstream effects even if the retaining baskets and weirs are postulated as inoperable.
- Even with the conservative assumptions, the head loss across the sump strainers only reached about 3% of the design value.

### 3.2.4 Review of Strainer Validation Testing

An independent review of the testing was conducted by Alden Research Laboratory (ALDEN). ALDEN concluded that the test loop scaling is conservative and is likely to provide test data that are conservative in predicting the IRWST strainer performance in terms of the percentage of debris transported to the strainer, blockages of the retaining baskets and the strainers, and the resulting head losses.

### 3.2.5 Conclusions

The key conclusions of the review of the IRWST Strainer Testing are:

- The three tier debris retention design is effective. The weirs and trash racks installed around the openings on the heavy floor (first level of defense) were shown to retain most of the debris. The retaining baskets (second level of defense) are sufficiently large to retain 96% of the debris.
- The combination of the weirs and trash racks and retaining baskets is effective in retaining most of the debris, thus preventing the debris from contributing to the strainer head loss. The strainer (third level of defense) has a large screen surface area to accommodate the small amount of debris that bypassed the first two levels of defense.
- The independent review of the IRWST strainer qualification testing program concluded that the test setup (i.e., weir/trash rack, retaining basket, strainer, back flush system) was appropriate and that the scaling of the test loop was conservative.

## 3.3 Other Considerations

### 3.3.1 Chemical Effects

The U.S. EPR uses tri-sodium phosphate (TSP) as a post-accident buffering solution and will predominantly use RMI; limited amounts of encapsulated fiber insulation; and little, if any, particulate-based insulation. Chemical reactions between the buffering solution and insulation material, and latent debris are expected to be minimal with

regard to the amount of precipitate formation and will not result in significant impact to strainer head loss and short term downstream effects.

### *3.3.2 Bypassing*

The U.S. EPR sump system flow path design is such that it is unlikely that unfiltered ECCS flow could bypass either the retaining baskets or the ECCS strainers, which comprise two of the three debris barriers. In all envisioned scenarios, the water level inside containment would not reach a level where it would be possible for unfiltered water to return to the RCS via the break location.

### *3.3.3 IRWST Cleanliness*

The IRWST serves as a water source, heat sink, and return reservoir and contains a large volume of borated water that is monitored for a homogeneous concentration, level, and temperature. The IRWST is an open pool within a partly immersed building structure. The walls of the IRWST have an austenitic stainless steel liner covering the immersed region of the building structure. The liner prevents interaction of the boric acid and concrete structure and provides water tightness.

During normal operations and refueling, there is the potential for debris to enter the IRWST and settle on its submerged surfaces. This "latent, resident" debris could become re-entrained post-accident. To maintain the cleanliness of the IRWST, the IRWST water inventory and access to the IRWST areas will be controlled and monitored. The fuel pool purification system (FPPS) is utilized to maintain the purity of the IRWST water inventory. IRWST programmatic controls for foreign material exclusion (FME) and tank cleaning will be implemented. A cleanliness control program will limit debris within containment.

### *3.3.4 Strainer Mechanical Integrity*

The ECCS strainers are designed to accommodate a 6.6 ft pressure differential. The maximum pressure drop across the strainers is estimated to be 4.9 ft based on

conservative assumptions. The strainers are Seismic Category I, safety-related components.

### *3.3.5 Non-Safety-Related Coatings*

Non-safety-related coatings will not be used within containment ZOIs.

# 4.0 REGULATORY OVERVIEW

The purpose of this section is to provide a brief overview of the related regulatory issues and an evaluation of the U.S. EPR conformance.

## *4.1 Generic Safety Issue 191*

GSI-191, "Assessment of Debris Accumulation on PWR Sump Performance," was initiated by the NRC in 1996 in response to a number of plant events and subsequent follow-on research regarding the adequacy of ECCS sump designs.

The issue of post-accident debris blockage arising from a LOCA or high energy line break (HELB) for which sump recirculation is required could potentially impact the plant's ability to demonstrate compliance with General Design Criterion 38, "Containment Heat Removal," and 10 CFR 50.46 (b) (5) as it relates long term post-LOCA core cooling requirements. The objective of GSI-191 is to prevent post-accident debris blockage that could impede the operation of the ECCS and CSS in the recirculation mode at PWRs during LOCAs or other HELB accidents for which sump recirculation is required.

## *4.2 Regulatory Guide 1.82 Rev. 3*

Regulatory Guide 1.82 Rev. 3, "Water Sources For Long-Term Recirculation Cooling Following a Loss-Of-Coolant Accident," provides guidelines for evaluating the adequacy of the availability of the sump and suppression pool for long-term recirculation cooling following a LOCA.

The primary safety concerns regarding long-term recirculation cooling following a LOCA are:

1. LOCA-generated and pre-LOCA debris materials transported to the debris interceptors (i.e., trash racks, debris screens, suction strainers) resulting in adverse blockage effects.

2. Post-LOCA hydraulic effects, particularly air ingestion.

3. The combined effects of items (1) and (2) on long-term recirculation pumping operability (i.e., NPSH available at the pump inlet).

The above safety concerns extend to the CSS for plants with containment designs where the CSS draws suction from the recirculation sump. In some cases, the CSS would draw from the recirculation sump significantly earlier than would the ECCS.

Debris resulting from a LOCA, together with debris that exists before a LOCA, could block the ECCS debris interceptors and result in degradation or loss of NPSH margin. Such debris can be divided into the following categories:

1. Debris that is generated by the LOCA and is transported by blowdown forces (e.g., insulation, paint).

2. Debris that is generated or transported by washdown.

3. Other debris that existed before a LOCA (e.g., corrosion material, sludge in a BWR suppression pool) and that may become suspended in the containment sump or suppression pool.

Debris can be further subdivided as follows:

1. Debris that have a high density and could sink but are still subject to fluid transport if local recirculation flow velocities are high enough.

2. Debris that have an effective specific gravity near 1.0 and tend to remain suspended or sink slowly and will nonetheless be transported by very low velocities or local fluid turbulence phenomena.

3. Debris that will float indefinitely by virtue of low density and will be transported to and possibly through the debris interceptors.

Debris generation, early debris transport, long-term debris transport, and attendant blockage of debris interceptors should be evaluated to show that the ability of the ECCS to provide long-term post-LOCA core cooling is not jeopardized. All potential debris sources should be evaluated, including but not limited to, the fire barrier material, insulation materials (e.g., fibrous, ceramic, and metallic), filters, corrosion material, and paints or coatings.

Regulatory Guide 1.82 provides separate guidance for PWR and BWR plants based on the design features of currently operating reactors. However, advanced PWR or BWR designs may employ design features that this regulatory guide only associates with the opposite reactor design (e.g., an advanced PWR design that employs an IRWST similar to the suppression pool of a current BWR design, or an advanced BWR design that employs a large dry containment similar to a current PWR design).

Therefore, for advanced PWR and BWR designs, the guidance provided in both the PWR and BWR sections of RG 1.82 that is appropriate and consistent with the plant's design features should be considered.

### *4.3 RG 1.82 Conformance Assessment*

An assessment of U.S. EPR conformance to RG 1.82 is provided in Appendix A. All 53 PWR-related guidance and 5 potentially applicable BWR guidance items were reviewed.

### 4.4 Generic Letter 2004-02

GL 2004-02 was issued to licensees of operating plants requesting that they demonstrate that corrective actions taken to address GSI-191 are adequate.

Additionally, GL 2004-02 requested the licensee provide information to assess the potential impact of debris blockage on emergency recirculation during design basis events.

Table B-1 of Appendix B provides U.S. EPR sump recirculation information as applicable to requested information outlined in GL 2004-02.

## 5.0 CONCLUSION

The U.S. EPR sump design has advanced and redundant features with respect to post-accident debris accumulation and ECCS recirculation sump strainer blockage. The U.S. EPR's ECCS recirculation system has multiple levels of debris removal and filtration that provide an effective system for preventing LOCA-generated debris from degrading ECCS performance or impeding core cooling. The conclusion is supported by the following information presented in this report:

1. The U.S. EPR has a minimal post-accident debris source term relative to current LWRs. RCS piping and components will be insulated with RMI; there will be little or no fibrous or micro-porous insulation and no calcium-silicate insulation within containment.

2. The three-tiered debris retention design of the U.S. EPR ECCS recirculation system is an effective solution to post-accident ECCS pump strainer clogging. The combination of weirs/trash racks and retaining baskets are effective in retaining most of the debris. As a result, very little debris will reach the ECCS strainers. The ECCS strainers have a large screen surface area to accommodate the small amount of debris that will reach them.

3. The U.S. EPR design conforms to the applicable RG 1.82 requirements as detailed in Table A-1 of Appendix A.

4. Test results using a conservative debris source term validate the performance of the U.S. EPR ECCS recirculation system features to prevent sump/strainer clogging.

# 6.0 REFERENCES

1. USNRC Regulatory Guide 1.82, Rev. 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," November 2003.

2. NEA/CSNI/R (95) 11 report: "Knowledge Base for Emergency Core Cooling System Recirculation Reliability," prepared by the USNRC for OECD, CSNI PWG 1 – February 1996.

3. GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors" NRC, September 2004.

# *Appendix A*
# *RG 1.82 Conformance Assessment*

## A.1 Regulatory Guide 1.82

NRC Regulatory Guide (RG) 1.82 describes acceptable methods and guidelines for evaluating the adequacy of plant design features and ECCS performance. RG 1.82 provides a framework for licensees to develop, demonstrate and implement a comprehensive response to GSI-191 resolution.

An assessment of U.S. EPR conformance to RG 1.82 has been performed. All 53 PWR-related guidance and 5 potentially applicable BWR guidance items were reviewed. The results of this assessment are detailed in Table A-1.

## Table A-1 RG-1.82 Conformance Assessment Matrix

| RG 1.82 Rev.3 | Water Resources for Long Term Recirculation Cooling following a Loss-of-Coolant Accident | |
|---|---|---|
| | **GUIDANCE** | **CONFORMANCE ASSESSMENT** |
| **C.** | **REGULATORY POSITION** | |
| | This section states regulatory positions on design criteria, performance standards, and analysis methods that relate to PWRs (Regulatory Position 1) and BWRs (Regulatory Position 2). As stated in the Introduction to this guide, the purpose of the guidance is to identify information and methods acceptable to the NRC staff for evaluating analytical techniques and implementing regulations related to water sources for long-term cooling of both existing and future reactor systems. The guidance, to a great extent, is generic and it may go beyond the current design of some operating reactor systems. | No response necessary – Introductory Material. |
| **1.** | **PRESSURIZED WATER REACTORS** | |
| **1.1** | **Features Needed to Minimize the Potential for Loss of NPSH** | |
| **1.1.1** | **ECC Sumps, Debris Interceptors, and Debris Screens** | |
| **1.1.1.1** | A minimum of two sumps should be provided, each with sufficient capacity to service one of the redundant trains of the ECCS and CSS. Distribution of water sources and containment spray between the sumps should be considered in the calculation of boron concentration in the sumps for evaluating post-LOCA subcriticality and shutdown margins. Typically, these calculations are performed assuming minimum boron concentration and minimum dilution sources. Similar considerations should also be given in the calculation of time for Hot Leg Switchover, which is calculated assuming maximum boron concentration and a minimum of dilution sources. | The U.S. EPR IRWST has 4 sumps, one for each of the 4 ECCS pumps. The IRWST is the sole water source (≈500,000 gallons) for these pumps. Sub-criticality analyses assume minimum boron concentrations while maximum boron concentrations are assumed for hot leg switchover timing.<br>Furthermore, dilution of the IRWST from internal sources has been evaluated. The risk of dilution is considered negligible because of the amount of dilutent |

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|---|---|---|
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| | | (≈53,000 gallons) required to achieve a significant (i.e., 10%) reduction in boron concentration is unrealistic (i.e., without going undetected). |
| **1.1.1.2** | To the extent practical, the redundant sumps should be physically separated by structural barriers from each other and from high-energy piping systems to preclude damage from LOCA, and, if within the design basis, main steam or main feedwater break consequences to the components of both sumps (e.g., trash racks, sump screens, and sump outlets) by whipping pipes or high-velocity jets of water or steam. | The IRWST is a 270° annular tank located in the space bounded by the reactor vessel support structure, the RCS loop area heavy floor (6.6 ft thick), the containment basemat, and the containment annular wall. These boundaries, in particular, the heavy floor, provide significant protection for the ECCS sumps (located on the IRWST floor); thereby precluding any post-LOCA induced damage. Hence, the U.S. EPR design eliminates the need for physically separated sumps. |
| **1.1.1.3** | The sumps should be located on the lowest floor elevation in the containment exclusive of the reactor vessel cavity to maximize the pool depth relative to the sump screens. The sump outlets should be protected by appropriately oriented (e.g., at least two vertical or nearly vertical) debris interceptors: (1) a fine inner debris screen and (2) a coarse outer trash rack to prevent large debris from reaching the debris screen. A curb should be provided upstream of the trash racks to prevent high-density debris from being swept along the floor into the sump. To be effective, the height of the curb should be appropriate for the pool flow velocities, as the debris can jump over a curb if the velocities are sufficiently high. Experiments documented in NUREG/CR-6772 and NUREG/CR-6773 have demonstrated that substantial quantities of settled debris could transport across the sump pool floor to the sump screen by sliding or tumbling. | U.S. EPR design features satisfy this guidance – weir, trash racks, retaining basket and ECCS sump strainer. ECCS sump strainer testing validates design.<br><br>Also, the ECCS sumps are located on the IRWST floor, which is also the top of the containment basemat. This maximizes the pool depth relative to the sump screens and pump suction. |

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| | **GUIDANCE** | **CONFORMANCE ASSESSMENT** |
| **1.1.1.4** | The floor in the vicinity of the ECC sump should slope gradually downward away from the sump to further retard floor debris transport and reduce the fraction of debris that might reach the sump screen. | NOT APPLICABLE:<br><br>The U.S. EPR design does not require that the floor in the vicinity of the ECC sumps be sloped away from the sump for the following reasons:<br>1. The IRWST, due to its isolated location, is not subject to heavy debris loading.<br>2. The retaining baskets will intercept any debris entering from the loop area above.<br>3. The ECCS sump screens have a significant amount of surface area and the effect of floor debris will be minimal.<br>4. The physical attachment of the ECC sump screen to the IRWST floor will also function as a berm.<br>5. All these features coupled with the very low flow velocities within the IRWST will significantly reduce the amount of floor debris that might reach the screen. |
| **1.1.1.5** | All drains from the upper regions of the containment should terminate in such a manner that direct streams of water, which may contain entrained debris, will not directly impinge on the debris interceptors or discharge in close proximity to the sump. The drains and other narrow pathways that connect compartments with | U.S. EPR design meets this guidance. Reactor Building drains terminate in the retaining baskets. |

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| | **GUIDANCE** | **CONFORMANCE ASSESSMENT** |
| | potential break locations to the ECC sump should be designed to ensure that they would not become blocked by the debris; this is to ensure that water needed for an adequate NPSH margin could not be held up or diverted from the sump. | |
| **1.1.1.6** | The strength of the trash racks should be adequate to protect the debris screens from missiles and other large debris. Trash racks and sump screens should be capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under design-basis flow conditions. When evaluating impact from potential expanding jets and missiles, credit for any protection to trash racks and sump screens offered by surrounding structures or credit for remoteness of trash racks and sump screens from potential high energy sources should be justified. | The 6.6 ft thick RCS loop area heavy floor and the heavy duty trash racks that cover the floor openings prevent missiles, large debris, and expanding jets from impacting the retaining baskets or the ECC screens. The floor openings are located on the periphery of the RCS loops, thereby reducing the trash rack profile for a majority of break locations. The trash racks are designed to prevent major debris from falling through the opening into the retaining baskets.<br><br>The retaining baskets and the ECC sump screens rely on the 6.6 ft thick heavy floor, the trash racks and distance for protection from jet impingement and missiles. Nevertheless, they are designed for the maximum expected debris loading and the corresponding differential pressure. |
| **1.1.1.7** | Where consistent with overall sump design and functionality, the top of the debris interceptor structures should be a solid cover plate that is designed to be fully submerged after a LOCA and completion of the ECC injection. The cover plate is intended to provide additional protection to debris interceptor structures from LOCA generated loads. However, the design should also provide means | NOT APPLICABLE:<br><br>The recommended guidance is not consistent with the U.S. EPR design. The U.S. EPR trash racks perform the debris intercept function and are located on the |

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| | **GUIDANCE** | **CONFORMANCE ASSESSMENT** |
| | for venting of any air trapped underneath the cover. | RCS loop area floor openings. The trash racks are designed to prevent major debris from falling through the opening into the retaining baskets. Therefore, a cover plate is not required. As such, the U.S. EPR design does not require venting. |
| **1.1.1.8** | The debris interceptors should be designed to withstand the inertial and hydrodynamic effects that are due to vibratory motion of a safe shutdown earthquake (SSE) following a LOCA without loss of structural integrity. | The trash racks, retaining baskets and ECC sump strainers are safety-related components and are designed to meet U.S. EPR Seismic Category I. |
| **1.1.1.9** | Materials for debris interceptors and sump screens should be selected to avoid degradation during periods of both inactivity and operation and should have a low sensitivity to such adverse effects as stress-assisted corrosion that may be induced by chemically reactive spray during LOCA conditions. | Materials of construction will be consistent with those used in other systems containing borated water. Hence, the trash racks, retaining baskets, ECC sump screens are made of austenitic stainless steel.<br><br>The acceptability of the material selection for post-LOCA service relative to chemical effects (i.e., sump chemistry) is part of the U.S. EPR design process and design requirements. |
| **1.1.1.10** | The debris interceptor structures should include access openings to facilitate inspection of these structures, any vortex suppressors, and the sump outlets. | U.S. EPR design provides access for IRWST component inspections. |
| **1.1.1.11** | A sump screen design (i.e., size and shape) should be chosen that will avoid the loss of NPSH from debris blockage during the period that the ECCS is required to operate in order to maintain long-term cooling or maximize the time before loss of NPSH caused by debris blockage when used with an active mitigation system (see | U.S. EPR ECCS sump screens are designed such that NPSH is not lost even with maximum debris loading. Their large surface area provides ample filtration area and debris build up is self-limiting on |

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| | **GUIDANCE** | **CONFORMANCE ASSESSMENT** |
| | Regulatory Position 1.1.4). | vertical surfaces due to their inverted trapezoidal shape. |
| **1.1.1.12** | The possibility of debris-clogging flow restrictions downstream of the sump screen should be assessed to ensure adequate long term recirculation cooling, containment cooling, and containment pressure control capabilities. The size of the openings in the sump debris screen should be determined considering the flow restrictions of systems served by the ECCS sump. The potential for long thin slivers passing axially through the sump screen and then reorienting and clogging at any flow restriction downstream should be considered. Consideration should be given to the buildup of debris at downstream locations such as the following: containment spray nozzle openings, HPSI throttle valves, coolant channel openings in the core fuel assemblies, fuel assembly inlet debris screens, ECCS pump seals, bearings, and impeller running clearances. If it is determined that a sump screen with openings small enough to filter out particles of debris that are fine enough to cause damage to ECCS pump seals or bearings would be impractical, it is expected that modifications would be made to ECCS pumps or ECCS pumps would be procured that can operate long term under the probable conditions. | The impact of debris clogging downstream of the ECC sump screens on components (pumps, valves, etc.) and fuel assemblies is expected to be negligible. An evaluation to support this conclusion is part of the U.S. EPR design process. This issue will be further assessed based on the results of industry consensus regarding confirmation of downstream effects.<br><br>The U.S. EPR design has two identical 0.08 x 0.08 inch mesh screens in series (retaining basket then ECCS sump strainer), the size of particulates passing downstream is anticipated to be quite small. Strainer testing indicated 10 ppm or less particulate in the downstream effluent.<br><br>The U.S. EPR fuel assembly inlet nozzle will filter out debris 0.10 inches and larger. Also, equipment specifications for ECC pumps, valves and other components handling IRWST water post-accident include a requirement that they be capable of handling particulates of 0.09 inches or less. |
| **1.1.1.13** | ECC and containment spray pump suction inlets should be designed to prevent degradation of pump performance through air | U.S. EPR design is such that the ECCS sumps are submerged sufficiently to |

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| | **GUIDANCE** | **CONFORMANCE ASSESSMENT** |
| | ingestion and other adverse hydraulic effects (e.g., circulatory flow patterns, high intake head losses). | preclude vortex formation and air ingestion. Additionally, sump screens are provided with vortex suppressors to provide an added measure of margin against vortex formation and air ingestion. |
| **1.1.1.14** | All drains from the upper regions of the containment building, as well as floor drains, should terminate in such a manner that direct streams of water, which may contain entrained debris, will not discharge downstream of the sump screen, thereby bypassing the sump screen. | U.S. EPR design calls for reactor building drains and similar lines to terminate within the retaining baskets thereby precluding bypass of the ECCS sump strainers. |
| **1.1.1.15** | Advanced strainer designs (e.g., stacked disc strainers) have demonstrated capabilities that are not provided by simple flat plate or cone-shaped strainers or screens. For example, these capabilities include built-in debris traps where debris can collect on surfaces while keeping a portion of the screen relatively free of debris. The convoluted structure of such strainer designs increases the total screen area, and these structures tend to prevent the condition referred to as the thin bed effect. It may be desirable to include these capabilities in any new sump strainer/screen designs. The performance characteristics and effectiveness of such designs should be supported by appropriate test data for any particular intended application. | NOT APPLICABLE:<br><br>The U.S. EPR design employs a simple strainer concept validated by testing. |
| **1.1.2** | **Minimizing Debris -** The debris (see Regulatory Position 1.3.2) that could accumulate on the sump screen should be minimized. | No response necessary – Introductory Material |

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| | **GUIDANCE** | **CONFORMANCE ASSESSMENT** |
| **1.1.2.1** | Cleanliness programs should be established to clean the containment on a regular basis, and plant procedures should be established for control and removal of foreign materials from the containment. | ADDRESSED BY COL APPLICANT:<br><br>This is a programmatic requirement. Refer to U.S. EPR FSAR COL Information Item 6.3-1 (Table 1.8-2). |
| **1.1.2.2** | Insulation types (e.g., fibrous and calcium silicate) that can be sources of debris that is known to more readily transport to the sump screen and cause higher head losses may be replaced with insulations (e.g., reflective metallic insulation) that transport less readily and cause less severe head losses once deposited onto the sump screen. If insulation is replaced or otherwise removed during maintenance, abatement procedures should be established to avoid generating latent debris in the containment. | NOT APPLICABLE:<br><br>This item applies to potential insulation replacement after the plant is licensed and is operating.<br><br>The U.S. EPR design specifies use of RMI for reactor coolant system piping and components. A limited amount of fibrous insulation will be permitted. As described in 1.1.2.1 above, containment cleanliness is ensured programmatically. |
| **1.1.2.3** | To minimize potential debris caused by chemical reaction of the pool water with metals in the containment, exposure of bare metal surfaces (e.g., scaffolding) to containment cooling water through spray impingement or immersion should be minimized either by removal or by chemical-resistant protection (e.g., coatings or jackets). | The need to address the potential impact of chemical reaction with the debris sources, filter differential pressure and other downstream effects is recognized by the U.S. EPR design program. This issue will be further assessed based on the results of industry consensus regarding confirmation of downstream effects. |
| **1.1.3** | **Instrumentation -** If relying on operator actions to mitigate the consequences of the accumulation of debris on the ECC sump screens, safety-related instrumentation that provides operators with an indication and audible warning of impending loss of NPSH for ECCS pumps should be available in the control room. | NOT APPLICABLE:<br><br>U.S. EPR design does not require operator action to backflush ECC sump screens; however, a non-safety-related |

| RG 1.82 Rev.3 | Water Resources for Long Term Recirculation Cooling following a Loss-of-Coolant Accident | |
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| | GUIDANCE | CONFORMANCE ASSESSMENT |
| | | backflushing system is provided. |
| 1.1.4 | **Active Sump Screen System** -An active device or system (see examples in Appendix B) may be provided to prevent the accumulation of debris on a sump screen or to mitigate the consequences of accumulation of debris on a sump screen. An active system should be able to prevent debris that may block restrictions found in the systems served by the ECC pumps from entering the system. The operation of the active component or system should not adversely affect the operation of other ECC components or systems. Performance characteristics of an active sump screen system should be supported by appropriate test data that address head loss performance | NOT APPLICABLE:<br><br>The U.S. EPR design does not require operator action to backflush ECC sump screens; however, a non-safety-related backflushing system is provided. |
| 1.1.5 | **Inservice Inspection** To ensure the operability and structural integrity of the trash racks and screens, access openings are necessary to permit inspection of the ECC sump structures and outlets. Inservice inspection of racks, screens, vortex suppressors, and sump outlets, including visual examination for evidence of structural degradation or corrosion, should be performed on a regular basis at every refueling period downtime. Inspection of the ECC sump components late in the refueling period will ensure the absence of construction trash in the ECC sump area. | U.S. EPR design provides suitable access to trash racks, retaining baskets and sump screens. Refer to U.S. EPR Technical Specifications Surveillance Requirement 3.5.2.6. |
| 1.2 | **Evaluation of Alternative Water Sources** - To demonstrate that a combination of the features and actions listed above are adequate to ensure long-term cooling and that the five criteria of 10 CFR 50.46(b) will be met following a LOCA, an evaluation using the guidance and assumptions in Regulatory Position 1.3 should be conducted. If a licensee is relying on operator actions to prevent the accumulation of debris on ECC sump screens or to mitigate the consequences of the accumulation of debris on the ECC sump screens, an evaluation should be performed to ensure that the operator has adequate indications, training, time, and system | NOT APPLICABLE:<br><br>U.S. EPR design does not require an alternate source of water (i.e., alternate to the water in the IRWST) to meet 10 CFR 50.46 (b) requirements following a LOCA. |

| RG 1.82 Rev.3 | Water Resources for Long Term Recirculation Cooling following a Loss-of-Coolant Accident | |
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| | capabilities to perform the necessary actions. If not covered by plant specific emergency operating procedures, procedures should be established to use alternative water sources that will be activated when unacceptable head loss renders the sump inoperable. The valves needed to align the ECCS and containment spray systems (taking suction from the recirculation sumps) with an alternative water source should be periodically inspected and maintained. | |
| **1.3** | **Evaluation of Long-Term Recirculation Capability -** The following techniques, assumptions, and guidance should be used in a deterministic, plant-specific evaluation to ensure that any implementation of a combination of the features and capabilities listed in Regulatory Position 1.1 are adequate to ensure the availability of a reliable water source for long-term recirculation following a LOCA. The assumptions and guidance listed below can also be used to develop test conditions for sump screens.<br><br>Evaluation and confirmation of (1) sump hydraulic performance (e.g., geometric effects, air ingestion), (2) debris effects (e.g., debris transport, interceptor blockage, head loss), and (3) the combined impact on NPSH available at the pump inlet should be performed to ensure that long-term recirculation cooling can be accomplished following a LOCA. Such an evaluation should arrive at a determination of NPSH margin calculated at the pump inlet. An assessment should also be made of the susceptibility to debris blockage of the containment drainage flow paths to the recirculation sump; this is to protect against reduction in available NPSH if substantial amounts of water are held up or diverted away from the sump. An assessment should be made of the susceptibility of the flow restrictions in the ECCS and CSS recirculation flow paths downstream of the sump screens and of the recirculation pump seal | Informational Material |

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| | and bearing assembly design to failure from particulate ingestion and abrasive effects to protect against degradation of long-term recirculation pumping capacity. | |
| **1.3.1** | **Net Positive Suction Head of ECCS and Containment Heat Removal Pumps** | |
| **1.3.1.1** | ECC and containment heat removal systems should be designed so that sufficient available NPSH is provided to the system pumps, assuming the maximum expected temperature of pumped fluid and no increase in containment pressure from that present prior to the postulated LOCA. (See Regulatory Position 1.3.1.2.) For sump pools with temperatures less than 212°F, it is conservative to assume that the containment pressure equals the vapor pressure of the sump water. This ensures that credit is not taken for the containment pressurization during the transient. For sub-atmospheric containments, this guidance should apply after the injection phase has terminated. For sub-atmospheric containments, prior to termination of the injection phase, NPSH analyses should include conservative predictions of the containment atmospheric pressure and sump water temperature as a function of time. | NPSH estimates based on existing calculations indicate sufficient available NPSH levels for required system pumps. |
| **1.3.1.2** | For certain operating PWRs for which the design cannot be practicably altered, conformance with Regulatory Position 1.3.1.1 may not be possible. In these cases, no additional containment pressure should be included in the determination of available NPSH than is necessary to preclude pump cavitation. Calculation of available containment pressure and sump water temperature as a function of time should underestimate the expected containment pressure and overestimate the sump water temperature when determining available NPSH for this situation. | NOT APPLICABLE<br><br>U.S. EPR design will conform to Regulatory Position 1.3.1.1. |
| **1.3.1.3** | For certain operating reactors for which the design cannot be practicably altered, if credit is taken for operation of an ECCS or containment heat removal pump in cavitation, prototypical pump | NOT APPLICABLE<br><br>U.S. EPR design precludes ECCS pump |

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| | tests should be performed along with post-test examination of the pump to demonstrate that pump performance will not be degraded and that the pump continues to meet all the performance criteria assumed in the safety analyses. The time period in the safety analyses during which the pump may be assumed to operate while cavitating should not be longer than the time for which the performance tests demonstrate that the pump meets performance criteria. | operation in cavitation. |
| **1.3.1.4** | The decay and residual heat produced following accident initiation should be included in the determination of the water temperature. The uncertainty in the determination of the decay heat should be included in this calculation. The residual heat should be calculated with margin | U.S. EPR design calculations for sump water temperature include decay heat (with margin) and all residual heat sources. |
| **1.3.1.5** | The hot channel [i.e., fluid] correction factor specified in ANSI/HI 1.1-1.5-1994 should not be used in determining the margin between the available and required NPSH for ECCS and containment heat removal system pumps. | The assessment of available NPSH for the U.S. EPR ECCS pumps conservatively does not use the hot fluid correction factor specified in ANSI/HI 1.1-1.5-1994. (This factor permits a reduction in NSPH required). |
| **1.3.1.6** | The calculation of available NPSH should minimize the height of water above the pump suction (i.e., the level of water on the containment floor). The calculated height of water on the containment floor should not consider quantities of water that do not contribute to the sump pool (e.g., atmospheric steam, pooled water on floors and in refueling canals, spray droplets and other falling water, etc.). The amount of water in enclosed areas that cannot be readily returned to the sump should not be included in the calculated height of water on the containment floor. | The assessment of available NPSH for the U.S. EPR ECCS pumps is based on the minimum post LBLOCA water level in the IRWST. |

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| **1.3.1.7** | The calculation of pipe and fitting resistance and the calculation of the nominal screen resistance without blockage by debris should be done in a recognized, defensible method or determined from applicable experimental data. | ECCS performance calculations properly treat pipe and fitting resistance and use a bounding value for ECCS screen resistance based on ECCS strainer testing results. |
| **1.3.1.8** | Sump screen flow resistance that is due to blockage by LOCA-generated debris or foreign material in the containment which is transported to the suction intake screens should be determined using Regulatory Position 1.3.4. | The assessment of available NPSH for the ECCS pumps is determined from screen pressure drop based on validation testing and the maximum expected debris loading. |
| **1.3.1.9** | Calculation of available NPSH should be performed as a function of time until it is clear that the available NPSH will not decrease further. | An alternative approach was taken in which the calculation of available NPSH for the ECCS pumps was determined using a bounding combination of pressure drop data and fluid temperature, rather than assessing available NPSH as a function of time. |
| **1.3.2** | **Debris Sources and Generation** | |
| **1.3.2.1** | Consistent with the requirements of 10 CFR 50.46, debris generation should be calculated for a number of postulated LOCAs of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated LOCAs are calculated. The level of severity corresponding to each postulated break should be based on the potential head loss incurred across the sump screen. Some PWRs may need recirculation from the sump for licensing basis events other than LOCAs. Therefore, licensees should evaluate the licensing basis and include potential break locations in the main steam and main feedwater lines as well in determining the most limiting conditions for sump operation. | The U.S. EPR design is based on the most penalizing break location with respect to debris generation.<br><br>The U.S. EPR does not require recirculation from the IRWST for non-LOCA events. It does collect water discharged inside containment from non-LOCA events (i.e., feed line breaks, steam line breaks). |

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| **1.3.2.2** | An acceptable method for estimating the amount of debris generated by a postulated LOCA is to use the zone of influence (ZOI). Examples of this approach are provided in NUREG/CR-6224 and Boiling Water Reactor Owners' Group (BWROG) Utility Resolution Guidance (NEDO-32686 and the staff's Safety Evaluation on the BWROG's response to NRC Bulletin 96-03). A representation of the ZOI for commonly used insulation materials is shown in Figure 3. | The ZOI method is used for determining the debris source for the U.S. EPR. |
| | • The size and shape of the ZOI should be supported by analysis or experiments for the break and potential debris. The size and shape of the ZOI should be consistent with the debris source (e.g., insulation, fire barrier materials, etc.) damage pressures, i.e., the ZOI should extend until the jet pressures decrease below the experimentally determined damage pressures appropriate for the debris source. | A spherical ZOI with a radius of 7-RCS pipe diameters about the limiting hot leg break location was used. This ZOI is considered to be conservative for the type of insulation used on the U.S. EPR based the NEA/CSNI/R (95) 11 report (Reference [2]). |
| | • The volume of debris contained within the ZOI should be used to estimate the amount of debris generated by a postulated break. | See below. |
| | • The size distribution of debris created in the ZOI should be determined by analysis or experiments. | See below. |
| | • The shock wave generated during the postulated pipe break and the subsequent jet should be the basis for estimating the amount of debris generated and the size or size distribution of the debris generated within the ZOI. Certain types of material used in a small quantity inside the containment can, with adequate justification, be demonstrated to make a marginal contribution to the debris loading for the ECC sump. If debris generation and debris transport data have not been determined experimentally for such material, it may be grouped with another like material existing in large quantities. For example, a small quantity of fibrous filtering material may be grouped with a substantially large quantity of fibrous insulation debris, and the debris generation and transport data for the filter material need not be determined experimentally. However, such | The U.S. EPR uses a bounding approach to determine the amount of debris generated within the ZOI. Specifically, all potential debris material within the ZOI is included in the debris source estimate. This debris then non-mechanistically assumed to be transported to the IRWST. The retaining basket head loss and ECC strainer head loss are conservatively calculated using this debris source term. |

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| | analyses are valid only if the small quantity of material treated in this manner does not have a significant effect when combined with other materials (e.g., a small quantity of calcium silicate combined with fibrous debris). | |
| **1.3.2.3** | A sufficient number of breaks in each high-pressure system that relies on recirculation should be considered to reasonably bound variations in debris generation by the size, quantity, and type of debris. As a minimum, the following postulated break locations should be considered.<br><br>• Breaks in the reactor coolant system (e.g., hot leg, cold leg, pressurizer surge line) and, depending on the plant licensing basis, main steam and main feedwater lines with the largest amount of potential debris within the postulated ZOI, • Large breaks with two or more different types of debris, including the breaks with the most variety of debris, within the expected ZOI,<br><br>• Breaks in areas with the most direct path to the sump,<br><br>• Medium and large breaks with the largest potential particulate debris to insulation ratio by weight, and<br><br>• Breaks that generate an amount of fibrous debris that, after its transport to the sump screen, could form a uniform thin bed that could subsequently filter sufficient particulate debris to create a relatively high head loss referred to as the 'thin-bed effect.' The minimum thickness of fibrous debris needed to form a thin bed has typically been estimated at 1/8 inch thick based on the nominal insulation density (NUREG/CR-6224). | See response to 1.3.2.1 above. |
| **1.3.2.4** | All insulation (e.g., fibrous, calcium silicate, reflective metallic), painted surfaces, fire barrier materials, and fibrous, cloth, plastic, or | The significant debris generating material within the ZOI has been considered in the |

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| | particulate materials within the ZOI should be considered a debris source. Analytical models or experiments should be used to predict the size of the postulated debris. For breaks postulated in the vicinity of the pressure vessel, the potential for debris generation from the packing materials commonly used in the penetrations and the insulation installed on the pressure vessel should be considered. Particulate debris generated by pipe rupture jets stripping off paint or coatings and eroding concrete at the point of impact should also be considered. | developing debris source estimate for the U.S. EPR. |
| **1.3.2.5** | The cleanliness of the containment during plant operation should be considered when estimating the amount and type of debris available to block the ECC sump screens. The potential for such material (e.g., thermal insulation other than piping insulation, ropes, fire hoses, wire ties, tape, ventilation system filters, permanent tags or stickers on plant equipment, rust flakes from unpainted steel surfaces, corrosion products, dust and dirt, latent individual fibers) to impact head loss across the ECC sump screens should also be considered. | Latent debris has been considered as part of the total debris source estimate. Control of material used and the overall cleanliness inside containment is a programmatic requirement. Refer to U.S. EPR FSAR COL Information Item 6.3-1 (Table 1.8-2). |
| **1.3.2.6** | In addition to debris generated by jet forces from the pipe rupture, debris created by the resulting containment environment (thermal and chemical) should be considered in the analyses. Examples of this type of debris would be disbondment of coatings in the form of chips and particulates or formation of chemical debris (precipitants) caused by chemical reactions in the pool. | Approved coatings will be used based on an assessment of the chemical effects on materials relative to debris generation and the industry approach to this topic. |
| **1.3.2.7** | Debris generation that is due to continued degradation of insulation and other debris when subjected to turbulence caused by cascading water flows from upper regions of the containments or near the break overflow region should be considered in the analyses. | All insulation and debris generating material within the ZOI has been conservatively assumed to reach the retaining baskets. Additionally, estimated quantities for latent debris, paint chips, and micro-porous insulating material have been included in the debris source term and are representative of such |

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| | | additional debris contribution from outside of the ZOI. |
| **1.3.3** | **Debris Transport** | |
| **1.3.3.1** | The calculation of debris quantities transported from debris sources to the sump screen should consider all modes of debris transport, including airborne debris transport, containment spray washdown debris transport, and containment sump pool debris transport. Consideration of the containment pool debris transport should include (1) debris transport during the fill-up phase, as well as during the recirculation phase, (2) the turbulence in the pool caused by the flow of water, water entering the pool from break overflow, and containment spray drainage, and (3) the buoyancy of the debris. Transport analyses of debris should consider: (1) debris that would float along the pool surface, (2) debris that would remain suspended due to pool turbulence (e.g., individual fibers and fine particulates), and (3) debris that readily settles to the pool floor. | The assessment of ECCS sump strainer blockage is conservatively bounded by the assumption that all available insulation and debris within the ZOI is transported to the IRWST. Also included in the debris source estimate is an amount of debris representing the contribution from outside the ZOI. |
| **1.3.3.2** | The debris transport analyses should consider each type of insulation (e.g., fibrous, calcium silicate, reflective metallic) and debris size (e.g., particulates, fibrous fine, large pieces of fibrous insulation). The analyses should also consider the potential for further decomposition of the debris as it is transported to the sump screen. | The assessment of ECCS sump strainer clogging conservatively assumes all debris is non-mechanistically transported to the IRWST. |
| **1.3.3.3** | Bulk flow velocity from recirculation operations, LOCA-related hydrodynamic phenomena, and other hydrodynamic forces (e.g., local turbulence effects or pool mixing) should be considered for both debris transport and ECC sump screen velocity computations. | Bounding assumptions are assumed for debris transport. IRWST surface area and volume result in low velocities that is conducive to debris settling. Additionally, flow velocity through the ECC sump screen at maximum flow is very low $\approx$ 0.8 inches/sec due to its large screen surface area. |
| **1.3.3.4** | An acceptable analytical approach to predict debris transport within | NOT APPLICABLE: |

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| | the sump pool is to use computational fluid dynamics (CFD) simulations in combination with the experimental debris transport data. Examples of this approach are provided in NUREG/CR-6772 and NUREG/CR-6773. Alternative methods for debris transport analyses are also acceptable, provided they are supported by adequate validation of analytical techniques using experimental data to ensure that the debris transport estimates are conservative with respect to the quantities and types of debris transported to the sump screen. | Conservative bounding assumptions regarding debris transport have been used; hence, use of CFD is unnecessary. |
| **1.3.3.5** | Curbs can be credited for removing heavier debris that has been shown analytically or experimentally to travel by sliding along the containment floor and that cannot be lifted off the floor within the calculated water velocity range. | U.S. EPR design incorporates a weir (curb) that prevents heavier debris from entering the retaining basket. This has been validated by testing. |
| **1.3.3.6** | If transported to the sump pool, all debris (e.g., fine fibrous, particulates) that would remain suspended due to pool turbulence should be considered to reach the sump screen. | Debris transported to the IRWST will first encounter the retaining baskets which will remove a majority of the debris. Debris which passes through the retaining baskets will not encounter any turbulence due to IRWST size. This has been demonstrated by testing.<br><br>Hence, suspended particulates were not directly considered downstream of the retaining basket. Instead, in AREVA studies, the ECC strainer was conservatively sized based on 2 times the maximum design head loss and the quantity of debris reaching the ECC strainer.<br><br>As part of the U.S. EPR design program, |

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| | | testing with different ratios of particulate to fiber volume will validate the above assumption (i.e., assess thin-bed layer effects). |
| **1.3.3.7** | The time to switch over to sump recirculation and the operation of containment spray should be considered in the evaluation of debris transport to the sump screen. | NOT APPLICABLE:<br><br>The U.S. EPR design features include an IRWST. As such, the ECCS pumps continuously operate in a recirculation mode post-LOCA. |
| **1.3.3.8** | In lieu of performing airborne and containment spray washdown debris transport analyses, it could be assumed that all debris will be transported to the sump pool. In lieu of performing sump pool debris transport analyses (Regulatory Position 1.3.3.4), it could be assumed that all debris entering the sump pool or originating in the sump will be considered transported to the sump screen when estimating screen debris bed head loss. If it is credible in a plant that all drains leading to the containment sump could become completely blocked, or an inventory holdup in containment could happen together with debris loading on the sump screen, these situations could pose a worse impact on the recirculation sump performance than the assumed situations mentioned above. In this case, these situations should also be assessed. | Bounding assumptions regarding debris transport and quantity of debris have been used in the evaluation of U.S. EPR ECCS sump performance. Furthermore, given the multiple pathways for water to drain to the IRWST, complete blockage of all pathways to the IRWST is considered to be not credible. |
| **1.3.3.9** | The effects of floating or buoyant debris on the integrity of the sump screen and on subsequent head loss should be considered. For screens that are not fully submerged or are only shallowly submerged, floating debris could contribute to the debris bed head loss. The head loss due to floating or buoyant debris could be | The U.S. EPR design is not affected by floating debris because even with the IRWST at minimum water level, the ECC sumps are significantly submerged. |

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| | minimized by a design feature to keep buoyant debris from reaching the sump screen | |
| **1.3.4** | **Debris Accumulation and Head Loss** | |
| **1.3.4.1** | ECC sump screen blockage should be evaluated based on the amount of debris estimated using the assumptions and criteria described in Regulatory Position 1.3.2 and on the debris transported to the ECC sump per Regulatory Position 1.3.3. This volume of debris should be used to estimate the rate of accumulation of debris on the ECC sump screen. | The performance of the U.S. EPR ECC sump strainers is based on bounding assumptions relative to the quantity of debris, ECC flow, and temperature conditions. |
| **1.3.4.2** | Consideration of ECC sump screen submergence (full or partial) at the time of switchover to ECCS should be given in calculating the available (wetted) screen area. For plants in which containment heat removal pumps take suction from the ECC sump before switchover to the ECCS, the available NPSH for these pumps should consider the submergence of the sump screens at the time these pumps initiate suction from the ECC sump. Unless otherwise shown analytically or experimentally, debris should be assumed to be uniformly distributed over the available sump screen surface. Debris mass should be calculated based on the amount of debris estimated to reach the ECC sump screen. (See Revision 1 of NUREG-0897, NUREG/CR-3616, and NUREG/CR-6224.) | The performance of the U.S. EPR ECC sump strainers is based on bounding assumptions relative to the quantity of debris, ECC flow, and temperature conditions. The debris mass is assumed to be uniformly distributed over the available ECC sump screen area. The U.S. EPR design is such that the ECC sumps remain continuously submerged. |
| **1.3.4.3** | For fully submerged sump screens, the NPSH available to the ECC pumps should be determined using the conditions specified in the plant's licensing basis. | NOT APPLICABLE:<br><br>The performance of the U.S. EPR ECCS sump strainers is based on bounding assumptions relative to the quantity of debris, ECC flow, and temperature conditions. |
| **1.3.4.4** | For partially submerged sumps, NPSH margin may not be the only failure criterion, as discussed in Appendix A. For partially | NOT APPLICABLE: |

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| | submerged sumps, credit should only be given to the portion of the sump screen that is expected to be submerged, as a function of time. Pump failure should be assumed to occur when the head loss across the sump screen (including only the clean screen head loss and the debris bed head loss) is greater than one-half of the submerged screen height or NPSH margin. | The U.S. EPR design is such that the ECC sumps remain continuously submerged. |
| **1.3.4.5** | Estimates of head loss caused by debris blockage should be developed from empirical data based on the sump screen design (e.g., surface area and geometry), postulated combinations of debris (i.e., amount, size distribution, type), and approach velocity. Because debris beds that form on sump screens can trap debris that would pass through an unobstructed sump screen opening, any head loss correlation should conservatively account for filtration of particulates by the debris bed, including particulates that would pass through an unobstructed sump screen. | The performance of the U.S. EPR ECC strainers is based upon strainer validation testing performed by AREVA. While the testing included a mix of particulates, micro-porous insulating material, paint chips, and mineral wool, no relevant thin-bed effects were observed.<br><br>The U.S. EPR design process will evaluate additional empirical data to further assess the presence or lack of thin bed effects. |
| **1.3.4.6** | Consistent with the requirements of 10 CFR 50.46, head loss should be calculated for the debris beds formed of different combinations of fibers and particulate mixtures (e.g., minimum uniform thin bed of fibers supporting a layer of particulate debris) based on assumptions and criteria described in Regulatory Positions 1.3.2 and 1.3.3. | See response to 1.3.4.5, above. |
| **2.** | **BOILING WATER REACTORS**<br><br>Regulatory Guide 1.82 (top of page 1.82-4) states that for advanced | The RG 1.82 guidance for BWRs was reviewed for applicability to the U.S. EPR. Most of the BWR guidance items have a similar, if not identical, counterpart item in |

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| | designs, the regulatory positions for both PWRs and BWRs should be considered (as appropriate to the plant's design). The example given, a PWR with an in-containment refueling water storage tank (IRWST) that is similar to the suppression pool in a BWR, is directly relevant to the U.S. EPR design. | the PWR guidance. The review did identify five items that are unique to BWRs. These items are assessed for U.S. EPR applicability below. |
| **2.3.1** | **Debris Sources and Generation** | |
| **2.3.1.7** | The amount of particulates estimated to be in the pool prior to a LOCA should be considered to be the maximum amount of corrosion products (i.e., sludge) expected to be generated since the last time the pool was cleaned. The size distribution and amount of particulates should be based on plant samples. | The amount of particulates contained in the IRWST prior to a LOCA is expected to be insignificant. Materials of construction for the IRWST are compatible with contained fluid chemistry; hence, no corrosion products are expected. In addition, the FPPS provides for IRWST cleaning and the tank internals and liner are constructed of austenitic stainless steel.<br><br>The U.S. EPR design process will consider the potential contribution from resident debris. |
| **2.3.2** | **Debris Transport** | |
| **2.3.2.2** | It should be assumed that LOCA-induced phenomena (i.e., pool swell, chugging, condensation oscillations) will suspend all the debris assumed to be in the suppression pool at the onset of the LOCA. | NOT APPLICABLE:<br><br>Unlike a BWR suppression pool, the IRWST does not receive lost coolant directly. Hence, phenomena contributing to significant mixing will be absent. |
| **2.3.2.3** | The concentration of debris in the suppression pool should be calculated based on the amount of debris estimated to reach the suppression pool from the drywell and the amount of debris and foreign materials estimated to be in the suppression pool prior to a | Debris transported to the IRWST will first encounter the retaining baskets which will remove a majority of the debris. The amount of particulates contained in the |

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| | postulated break. | IRWST prior to a LOCA is expected to be insignificant as explained in 2.3.1.7 above.<br><br>The U.S. EPR design process will include an assessment to include an estimate of debris material resident in the IRWST prior to the LBLOCA. |
| **2.3.2.4** | Credit should not be taken for debris settling until LOCA-induced turbulence in the suppression pool has ceased. The debris settling rate for the postulated debris should be validated analytically or experimentally. | Unlike a BWR suppression pool, the IRWST does not receive lost coolant directly. Hence, phenomena contributing to significant mixing and turbulence will be absent. Additionally, as indicated in 2.3.2.3 above, the amount of debris in the IRWST beyond the retaining baskets is expected to be minimal. |
| **2.3.3** | **Strainer Blockage and Head Loss** | |
| **2.3.3.2** | The flow rate through the strainer should be used to estimate the rate of accumulation of debris on the strainer surface. | The combined flow from LHSI and MHSI is used to determine the ECC strainer differential pressure. Since a bounding calculation approach is used, the estimate of rate of debris accumulation on the strainer surface was not determined. |

# *Appendix B*
# *Generic Letter 2004-02 Information Matrix*

## B.1 GL 2004-02

GL 2004-02 was issued to licensees of operating plants requesting that they demonstrate that corrective actions taken to address GSI-191 are adequate.

Additionally, GL 2004-02 requested the licensee provide information to assess the potential impact of debris blockage on emergency recirculation during design basis events.

Table B-1 provides U.S. EPR sump recirculation information in response to requested information outlined in GL 2004-02.

## Table B-1 GL 2004-02 Information Matrix

| GL 2004-02 | Potential Impact of Debris Blockage on Emergency Recirculation During design Basis Accidents At Pressurized-Water Reactors | |
|---|---|---|
| | **Requested Information** | **Observation/Comment** |
| **2.(d)(i)** | The minimum available NPSH margin for the ECCS and CSS pumps with an unblocked screen. | The NPSH margins are:<br>Low head safety injection (LHSI) pumps: 2.57 ft.<br>Medium head safety injection (MHSI) pumps: 4.82 ft. |
| **2.(d)(ii)** | The submerged area of the sump screen at this time and the percent of submergence of the sump screen (i.e., partial or full) at the time of switchover to sump recirculation | Switchover is not part of the U.S. EPR design.<br>However, the U.S. EPR design is such that the ECCS sump screens remain completely and continuously submerged. (Refer to Section 3.1.1.5) |
| **2.(d)(iii)** | The maximum head loss postulated from debris accumulation on the submerged sump screen, and a description of the primary constituents of the debris bed that result in this head loss. In addition to debris generated by jet forces, from the pipe rupture, debris created by the resulting containment environment (thermal and chemical) and CSS washdown should be considered in the analyses. Examples of this type of debris are disbonded coatings in the form of chips and particulates and chemical precipitants caused by chemical reactions in the pool. | Section 3.1.1.4 (NPSH Assessment) provides the maximum head loss for the ECCS pumps. The performance of the U.S. EPR ECCS strainers is based upon studies and strainer validation testing performed by AREVA. The testing included a mix of particulates, micro-porous insulating material, paint chips, latent debris, and mineral wool.<br><br>Approved coatings will be used based on an assessment of the chemical effects on materials relative to debris generation. |
| **2.(d)(iv)** | The basis for concluding that the water inventory required to ensure | The minimum IRWST water level for |

| GL 2004-02 | Potential Impact of Debris Blockage on Emergency Recirculation During design Basis Accidents At Pressurized-Water Reactors | |
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| | **Requested Information** | **Observation/Comment** |
| | adequate ECCS and CSS recirculation would not be held up or diverted by debris blockage at choke points in containment recirculation sump return flowpaths. | ECCS recirculation is -10.2 ft. This level considers the initial IRWST water inventory prior to the LOCA event, return water from the LOCA, quantities of water in containment that do not return to the IRWST (pooled water on the containment floor, atmospheric steam, wetted areas, trapped water pockets at various locations). The return flow path to the IRWST is via 4 large heavy floor openings that are each provided with a weir and trash rack. |
| **2.(d)(v)** | The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen or containment spray nozzles). The discussion should consider the adequacy of the sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface. | The impact of debris clogging downstream of the ECCS sump screens on components (pumps, valves etc) and fuel assemblies is expected to be negligible. An evaluation to support this conclusion is part of the U.S. EPR design process. This issue is to be addressed based on the results of industry consensus regarding confirmation of downstream effects.<br><br>The U.S. EPR design has two identical 0.08 x 0.08 inch mesh screens in series (retaining basket then ECCS sump strainer), the size of particulates passing downstream is anticipated to be quite small. Strainer testing indicated 10 ppm or less particulate in the downstream |

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| | | effluent. The U.S. EPR design recognizes the need to maintain that there are no screen gaps or breaches by which ECCS supply water can bypass the screens.<br><br>The U.S. EPR fuel inlet nozzle will filter out debris 0.10 inches and larger. Also, AREVA studies recommend that equipment specifications for ECCS pumps, valves and other components handling IRWST water post-accident include a requirement that they be capable of handling particulates of 0.09 inches or less. |
| **2.(d)(vi)** | Verification that close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids. | See response to 2.(d)(v), above. |
| **2.(d)(vii)** | Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under predicted flow conditions. | The 6.6 ft thick RCS loop area heavy floor and the heavy duty trash racks that cover the floor openings prevent missiles, large debris, and expanding jets from impacting the retaining baskets or the ECCS screens. The floor openings are located on the periphery of the RCS loops, thereby reducing the trash rack profile for a majority of break locations. The trash racks are significantly robust to prevent major debris from falling through the |

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| | | opening into the retaining baskets. They are safety-related Seismic Category I components.<br><br>The retaining baskets and the ECCS sump screens rely on the 6.6 ft thick heavy floor, the trash racks and distance for protection from jet impingement and missiles. Nevertheless, they are designed for the maximum expected debris loading and the corresponding differential pressure. The ECCS sump screens are designed to accommodate a 6.6 ft pressure differential. The maximum pressure drop across the strainers is estimated to be 4.9 ft based on conservative assumptions. |
| **2.(d)(viii)** | If an active approach (e.g., backflushing, powered screens) is selected in lieu of or in addition to a passive approach to mitigate the effects of the debris blockage, describe the approach and associated analyses. | The U.S. EPR design does not take credit for an active approach to reduce/eliminate the effects of debris blockage. |