US-APWR Sump Strainer Performance

Non-Proprietary Version

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List of Acronyms

APWR	Advanced Pressurized Water Reactor
CO/L	Cross Over Leg
CSS	Containment Spray Systems
DBA	Design Basis Accident
DCD	Design Control Document
ECCS	Emergency Core Cooling Systems
ECC/CS	Emergency Core Cooling and Containment Spray
GR	Guidance Report
HELB	High Energy Line Break
HVAC	Heating, Ventilation, and Conditioning
LOCA	Loss of Coolant Accident
LBLOCA	Large Break LOCA
MCP	Main Coolant Pipe
MHI	Mitsubishi Heavy Industries, LTD.
MS/FW	Main Steam and Feed Water
NPSH	Net Positive Suction Head
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
PWR	Pressurized Water Reactor
PZR	Pressurizer
RCP	Reactor Coolant Pump
RG	Regulatory Guide
RHR	Residual Heat Removal
RMI	Reflective Metal Insulation
RWSP	Refueling Water Storage Pit
RV	Reactor Vessel
SBLOCA	Small Break LOCA
SE	Safety Evaluation
SG	Steam Generator
SI	Safety Injection
TBE	Thin Bed Effect
ZOI	Zone of Influence

1.0 INTRODUCTION

This technical report summarizes the design and evaluation of the standard US-APWR sump strainer, and supports the US-APWR Design Control Document (DCD), Chapter 6, Subsections 6.2 “Containment Systems”, and 6.3 “Emergency Core Cooling Systems (ECCS). (Reference [1]) The design and evaluation described herein were in accordance with the Regulatory Guide 1.82 Rev.3. (Reference [2])

In this report, Chapter 2 contains a description of the strainer, its type, location, and a summary of design features relative to the insulation and coating systems which are generally considered as the potential debris sources. Chapter 3 describes the design and the evaluation of strainer performance with respect to the debris head loss. Chapter 4 discusses the downstream effect of the strainer. Finally, Chapter 5 presents the conclusions of the US-APWR sump strainer performance.

2.0 DESIGN DESCRIPTION

2.1 ECC/CS strainer

The US-APWR emergency core cooling and containment spray (ECC/CS) strainers are designed to be consistent with Regulatory Guide (RG) 1.82 as follows:

- Four independent sets of strainer system are provided
- The strainers are installed on the bottom floor of the containment to collect the blowdown water during the accident
- The design precludes the drain water impinging directly on the strainers
- The strainers are well isolated from postulated pipe break jets and missiles
- The strainer's large surface provides low flow rate on the strainer surface and mitigates debris head loss
- The perforate plates are designed to prevent blockage of core cooling
- The strainers are constructed of corrosion resistant materials
- The strainers are sized to maintain the performance of the safety-related pumps
- The strainers are designed to meet seismic Category I requirements
- The strainers are inspected periodically, during plant shutdown

As shown in the US-APWR DCD Figures 6.2.2-8 and 6.2.2-9, four independent sets of ECC/CS strainers are provided inside the in-containment refueling water storage pit (RWSP). The ECC/CS strainers prevent debris from entering the safety systems that are required to maintain the post-LOCA long-term cooling performance. The RWSP is located at the lowest part of the containment in order to collect containment spray water and blowdown water by gravity. The RWSP is compartmentalized by a concrete structure against the upper containment area, and connecting pipes that drain the collected water from the upper containment are provided in the ceiling of the RWSP. The RWSP protects the ECC/CS strainers from missiles. The ECC/CS strainers are installed on the bottom floor of the RWSP, and are designed to be fully submerged during all postulated events requiring the actuation of the ECCS.

The fully submerged strainers, in combination with the Safety Injection (SI) pump and the Containment Spray/Residual Heat Removal (CS/RHR) pump elevation, provide sufficient NPSH to ensure continuous suction availability without cavitation. The strainer sizing accommodates the estimated amount of debris potentially generated in containment. The RWSP water chemistry is controlled so as to minimize the chemical effects between the sump water and potentially corrosive materials in containment.

The standard US-APWR design utilizes a passive disk layer type of strainer systems. Figure 2-1 shows a plan view of the disk type strainer system used in the US-APWR. The strainer is principally constructed of perforated plate with a square flange at the bottom for attachment to the supporting plate, which is covered on the sump pit. A manifold core tube welded to the flange penetrates near the center of the layer disks, and guides the clean water filtered by the layer disks into the sump pit. The joint gap between the components of the strainer is controlled to preclude debris from bypassing the perforate plates. The strainers and supporting plates will be constructed of corrosion-resistant stainless steel. The nominal diameter of holes is designed to be equal or less than 1/16”, consistent with the narrow gap in the downstream systems of the strainer. The downstream narrow gap is discussed in Section 4.0 of this report.

The RWSP is filled by 651,000 gallons of borated water during normal operation, and is designed to hold a sufficient water volume during a loss of coolant accident (LOCA). An adequate water level is maintained to submerge the strainer in case of a LBLOCA. The strainers are installed so as to submerge the top of the layer disk 8” under the minimum water level. The water balance of the RWSP is summarized in US-APWR DCD Table 6.2.1-3, and its calculation is discussed in Section 3.7 of this report.

The strainer assemblies will provide 2,150 ft^2 of strainer surface area per safety train. The evaluation of the debris head loss based on this surface area is provided in Section 3.6 of this report.

2.2 Insulation

The standard US-APWR design utilizes the zone of influence (ZOI) method for the evaluation of debris generation, as discussed in Section 3.1 and Section 3.2 of this report. The ZOI represents the zone where a given high-energy line break (HELB) will generate debris that may be transported to the strainer. The size of the ZOI is defined in terms of pipe diameters and determined based on the pressure contained by the piping and the destruction pressure of the insulation surrounding the break site. The ZOI for specific insulation types are provided in the approved methodology, NEI 04-07 Guidance Report (GR) amended by NRC Safety Evaluation (SE). (Reference [3])

In the Section 3.3.4.2.1 (Table 3-2) of the SE, the reflective metal insulation (RMI) is seen to require a largest destruction pressure among the types of insulation made of fibrous and particulate materials. Therefore, the application of RMI for the pipe lines and components subject to jet impingement from a HELB will minimize the generation of insulation debris, rather than the use of fibrous/particulate material insulations.

The US-APWR design considers that the pipe breaks in the primary coolant system piping have the potential need for reliance on ECCS sump recirculation. In addition, the secondary side system, i.e. main steam and feed water (MS/FW) pipe breaks also require sump operation.

As a result, the US-APWR design utilizes the RMI, to the greatest extent practicable, for the pipe lines and components subject to jet impingement from a HELB, in order to mitigate the generation of insulation debris. Equivalent debris resistant insulation that contains fibrous/particulate insulation material capsuled by stainless steel cassette may be used, as long as the generation of fibrous/particulate debris is negligible. The use of fibrous/particulate insulations which are more subject to destruction by HELB is limited in the zone of influence inside containment.

Following is the design of the insulation applying for the US-APWR equipment and pipe lines:

Equipment

RMI is applied to the reactor vessel (RV), the reactor coolant pumps (RCP), the steam generators (SG), and the pressurizer (PZR) in the areas that have large amount of insulation to be potentially subject to jet impingement from a HELB.

There is no other equipment to be insulated inside containment of the US-APWR. In addition, the heating, ventilation, and air conditioning (HVAC) of the US-APWR requires no insulation, nor even the ventilation filters, which are considered as the potential debris sources caused by HELB.

Pipe lines

RMI is applied for the main coolant pipes (MCP) connecting the RV, the SG, and the RCP, and MS/FW pipe lines. RMI is also applied for the pipe lines located inside the ZOI which are subject to the jet impingement of HELB. However, for the flowing pipe lines, RMI may not be applied.

- Pipe lines equal or less than 1 inch diameter (RMI is practically un-manufacturable)
- The steam generator blow down line (Unfeasible due to large dead load for pipe stress analysis)

2.3 Coatings

The standard US-APWR utilizes a DBA qualified and Acceptable coating system in containment. The criteria for those coating systems are contained in ANSI N101.2, “Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities (Reference [4]),” and its successor document, ASTM D 3911, “Standard Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design Basis Accident (DBA) Conditions (Reference [5]).”

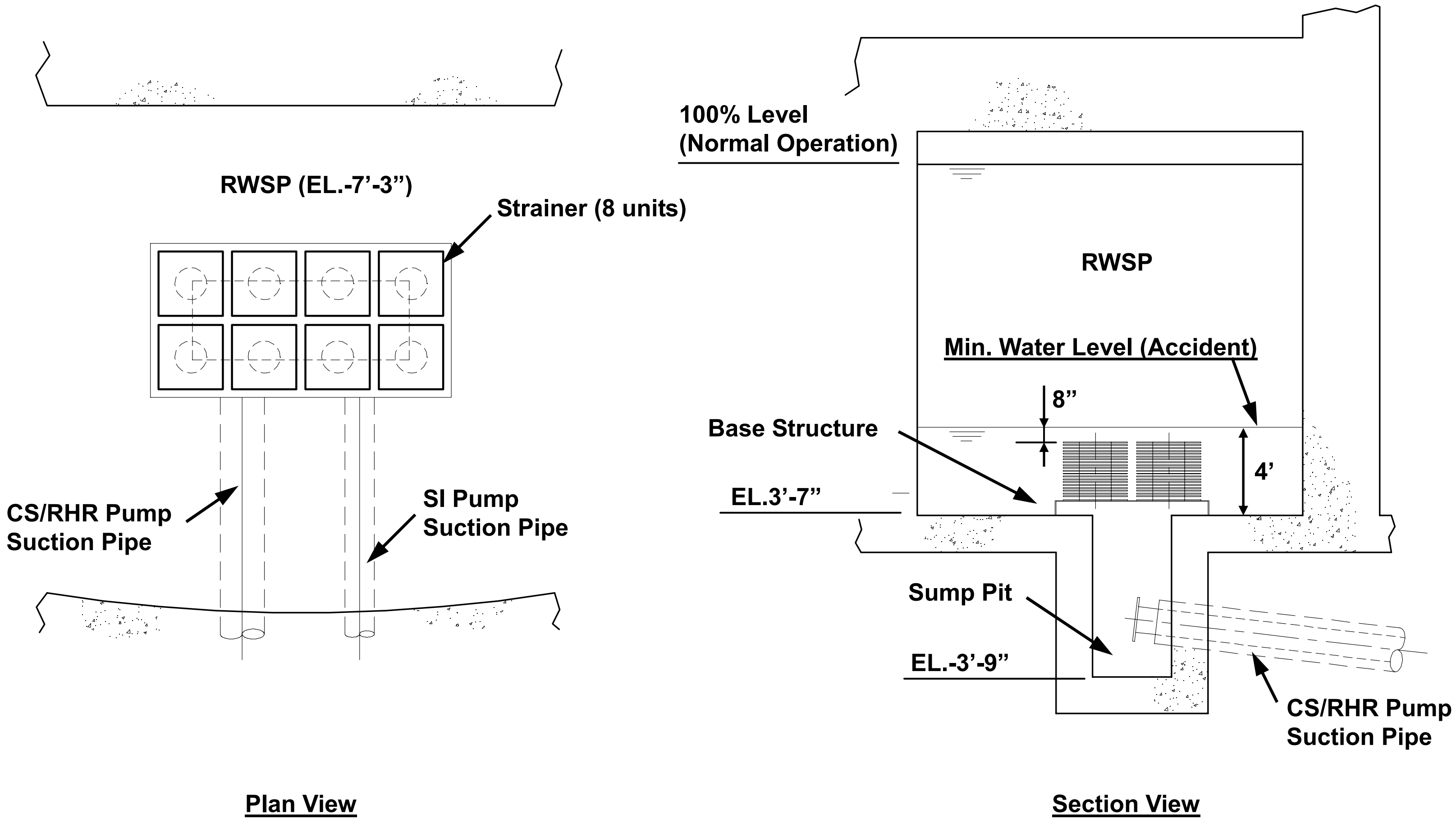


Figure 2-1 ECC/CS Strainer Arrangement

3.0 EVALUATION OF STRAINER PERFORMANCE

3.1 Break Selection

The US-APWR design considers that the pipe breaks in the primary coolant system piping have the potential need for reliance on ECCS sump recirculation. A reactor coolant system (RCS) piping large break loss of coolant accident (LBLOCA) and certain RCS piping small break LOCAs (SBLOCAs) would also require ECC/CS sump recirculation. In addition, the secondary side system, i.e. Main Steam and Feed Water (MS/FW), pipe breaks require sump operation.

For the break selection, the following break location criteria, which are recommended in the SE (Reference [3]) and comply with RG 1.82, are considered:

Break Criteria

1. Pipe break in the RCS or MS/FW with the largest potential for debris
2. Large breaks with two or more different types of debris
3. Breaks with the most direct path to the sump
4. Large breaks with the largest potential particulate debris to insulation ratio by weight
5. Breaks that generate a “thin-bed” - high particulate with 1/8" fiber bed

According to Section 3.3.4.1 of the SE, the breaks are considered for selection only for 2" in diameter and larger HELB pipes. Based on the criteria, the pipe lines considered to be break for sump strainer performance of the US-APWR are listed in Table 3-1.

Section 3.3.5 of the SE describes an approach to the break selection process which includes beginning the evaluation at an initial location along a pipe and stepping along in equal increments (5 foot increments) considering breaks at each sequential location. However, it is not necessary to consider 5-ft increments for the US-APWR evaluation, because of the following conservative considerations:

As discussed in Section 2.2 of this report, the RMI is used for the equipment and pipe lines located in the ZOI to the greatest extent practicable. The use of fibrous insulation is minimized, so that only a small amount of fibrous debris will be generated from small diameter pipe line insulation. Particulate insulations are not used inside the ZOI of HELB. Therefore, only the

RMI debris and fibrous debris are considered as the potential insulation debris for the US-APWR.

The amounts of RMI and fibrous insulation debris are estimated conservatively for the US-APWR. In addition, the generation of RMI debris and fibrous debris are combined conservatively, regardless of the location of pipe break.

As shown in Table 3-2, the diameter of the ZOI for RMI is defined as 2 inside diameters of the broken pipe. Therefore, most of RMI debris is generated from broken pipe itself. In order to maximum RMI debris generation, the MCP which has a largest inner diameter is selected as the location of the pipe break, which generates largest amount of RMI debris inside containment.

Figures 3-1 and 3-2 show a spherical region within a distance equal to 2 inside diameters of the MCP when the cross over leg (CO/L) nozzle of the SG is broken. As shown, only a small portion of the RMI installed on CO/L and SG is included in the ZOI, so that the generation of RMI debris is relatively limited. Even if the break selection process which includes stepping along in equal increments (5 foot increments) and considering breaks at each sequential location is utilized, the amount RMI debris generated will never exceed all amount of RMI installed on a CO/L. In other words, if all amount of RMI installed on a CO/L is considered as debris, it is not necessary to consider 5-ft increments for break selection. As a result, the standard US-APWR design considers conservatively that all the RMI installed on a CO/L is considered as debris in the evaluation.

For the fibrous insulation debris generation, a conservative evaluation is performed. As discussed in Section 2 of this report, the following pipe lines located within the ZOI of HELB will be applied fibrous insulation, and potentially generate the fibrous debris.

- Pipe lines equal or less than 1 inch diameter
- The steam generator blow down line

The diameter of the ZOI for fibrous (NUKON) is defined 17 inside diameters of the broken pipe (Table 3-2), the Figures 3-3, and 3-4 show a spherical region within a distance equal to 17 inside diameters of the MCP when the CO/L nozzle of SG is broken. As shown, all of the region inside a SG compartment is enveloped horizontally by the ZOI. Therefore, the worst case of fibrous debris generation is that all of fibrous insulation inside one SG, or PZR compartment, is considered to become debris. Further discussion about the worst case of fibrous debris generation of the US-APWR is provided in the Section 3.2 of this report.

The maximum amounts of RMI debris and fibrous insulation debris are estimated and combined in the debris head loss calculation, regardless the location of pipe break. This conservative design assumption envelops the break criteria No.1 and No.2.

For Break Criterion 3, it is not necessary for the US-APWR to identify the most direct path to the RWSP, because of the conservative assumption regarding debris transport ratio, as discussed in Section 3.4 of this report.

Since particulate insulation is excluded from the ZOI of HELB, any particulate debris will be generated from coatings and latent debris. As discussed in Section 3.2 of this report, the coatings debris and latent debris of the US-APWR are conservatively considered constant volumes, regardless of the break location. Therefore, the US-APWR does not require identifying the specific break location which generates maximum volume of particulate debris.

For the evaluation of “thin-bed effect (TBE)” associated with the Break Criterion 5, it is well known that the head loss due to TBE depends on the amount of particle debris. As discussed in Section 3.5.3, the worst case of particulate debris generation is considered in the evaluation.

3.2 Debris Generation

The sources of debris at the US-APWR are the insulation debris, coatings debris, and latent debris. For the insulation debris, the US-APWR evaluation concluded that the RMI and fibrous insulation were the potential debris sources following a HELB.

The US-APWR design defines a zone of influence for the evaluation of debris generation. The damage pressures and corresponding volume-equivalent spherical ZOI of each insulation type are extracted from the guidance of the SE, and are provided in Table 3-2.

In estimating the US-APWR insulation debris generation, a more conservative evaluation rather than ZOI methodology was applied. As discussed in Section 3.1, all of RMI insulation installed on a CO/L was assumed to become debris. In addition, all fibrous insulation inside the ZOI would become fibrous debris, exclude that outside robust barriers. Figures 3-3 and 3-4 show the robust barriers, such as primary and secondary shield walls, which protect components behind them from jet impingement. The estimated amount debris was conservative and enveloped the amount of debris generated at any pipe break locations.

Table 3-3 provides the location of fibrous insulation in each area inside containment. As shown, SG compartment (A) includes largest amount of fibrous insulation. Therefore, the amount of fibrous insulation debris of the US-APWR was estimated assuming that all fibrous insulation inside SG compartment (A) would be broken by jet impingement.

As for the coating debris of the US-APWR, the ZOI for qualified coatings is a sphere with a radius 10 times the MCP inner diameter, which generates largest amount of coating debris. In the evaluation, the volume of coating debris was calculated by multiplying the surface area of the ZOI sphere by the thickness of the coating film. The thickness of the coating film was defined based on the past experience, and was conservatively assumed to be 650 (μm). As a result, the maximum volume of coating debris was established as 0.51 (m^3).

Latent debris is defined as unintended dirt, dust, paint chips, and fibers, which principally consist of fiber and particle debris. The evaluation used a conservative assumption of 200 (lbm) as a the upper bound amount of latent debris. The particulate and fiber mix of the latent debris was assumed to be 15% fiber as per the guidance of the SE.

The amount of insulation, coating and latent debris assumed for the US-APWR is provided in Table 3-4.

3.3 Debris Characteristics

The debris characteristics used in the US-APWR evaluation are presented in Table 3-5. The size distribution is not required for the analysis, because all of generated debris is considered to be small, and is assumed all the debris is transported to the RWSP.

3.4 Debris Transport

Debris transport is the estimation of the fraction of debris that is transported from debris sources (break location) to the sump strainer. NEI GR provides the generic transport logic tree to evaluate the fraction of debris for the typical conventional PWR plants.

While the NEI methodology reasonably reduces the fraction of debris that is transported, the US-APWR assumes that all the generated debris will be transported to the RWSP. This assumption gives a most conservative uppe limit for the debris transport evaluation.

3.5 Debris Head Loss

The head loss due to RMI, fibrous and particulate mixture debris bed is estimated with the guidance of the SE, which originally refers the NUREG/CR-6808 (Reference [6]) and NUREG/CR-6224 (Reference [7]) to provide the head loss correlation. The following assumptions used in the US-APWR debris head loss evaluation:

- All the fibrous and particulate debris is uniformly distributed on the strainer surface.
- The debris bed is homogeneous in composition. In other words, the particulate to fiber mass ratio remains constant through the debris bed.
- The head loss due to a mixture of RMI, fibrous and particulate debris is the sum of the head loss due to RMI debris and the head loss due to fibrous and particulate debris.
- A passive disk layer type strainer utilized for the US-APWR is assumed that its surface consists of flat surface plate for the evaluation.

3.5.1 Head Loss due to RMI Debris

The head loss for RMI debris bed on the sump screen surface depends mainly on the accumulation at the sump screen and the type and size distribution of RMI debris. The key parameter needed to evaluate pure RMI head loss is the surface area of the RMI bed on the screen. The commonly accepted empirical correlation for RMI is:

$$\Delta H = [1.56E\text{-}05 / (Kt)^2]\ U^2\ A_{foil} / Ac$$

Where:

Kt : the interfoil gap thickness, (ft)

ΔH : the head loss, (feet-of-water)

U : the fluid approach velocity, (ft/sec) [5200 gpm]

A_{foil} : the RMI foil surface area (ft^2)

Ac : the strainer surface area (ft^2) [2150 ft^2]

Based on the above correlation, the head loss due to RMI debris was calculated, and its results are provided in Table 3-6.

3.5.2 Head Loss due to Fibrous and Particulate Debris

The head loss due to a mixture of fibrous and particulate debris is calculated by means of the NUREG/CR-6224 head loss correlation

$$\frac{\Delta H}{L_m} = \Lambda \cdot 3.5Sv^2 \cdot {\alpha_m}^{1.5}\left(1+57{\alpha_m}^3\right)\mu \cdot U + 0.66Sv \cdot \frac{\alpha_m}{1-\alpha_m}\rho \cdot U^2$$

Where:

ΔH : the head loss

Sv : the surface to volume ratio of the debris

μ : the dynamic viscosity of water [70° F]

U : the fluid approach velocity

ρ : the density of water

α_m : the mixture debris bed solidity

ΔL_m : the actual mixed debris bed thickness

Λ : conversion factor (4.1528 x 10-5 (ft-water/inch) / (lbm/ft^2/sec^2) for English units

The fluid approach velocity, U, is given in terms of the volumetric flow rate and the effective strainer surface area as:

$$U = \frac{Q}{A}$$

Where:

Q : the total volumetric flow rate through the strainer

A : the strainer surface area

The mixed debris bed solidity, α_m, is given by:

$$\alpha_m = \left(1 + \frac{\rho_f}{\rho_p}\eta\right)\alpha_0 c$$

Where:

α_0 : the solidity of the original fiber blanket (i.e., the “as fabricated” solidity)

η : mp/mf, the particulate-to-fiber mass ratio in the debris bed

m_p : Σ mi is the total particulate mass (lbm)

ρ_f : the fiber density (lbm/ft^3)

ρ_p : the average particulate material density (lbm/ft^3) = $\Sigma \rho_i V_i / \Sigma V_i$

c : the head-loss-induced volumetric compression of the debris (inches/inch).

For debris deposition on a flat surface of a constant size, the compression (c) relates the actual debris bed thickness, ΔL_m, and the theoretical fibrous debris bed thickness, ΔL_o (inches), via the relation:

$$c = \frac{\Delta L_0}{\Delta L_m}$$

Compression of the fibrous bed due to the pressure gradient across the bed is also taken into account. The relation that accounts for this effect, which must be satisfied in parallel to the previous equation for the head loss, is given by (valid for ratios of $\Delta H / \Delta Lo > 0.5$ ft-water/inch-insulation):

$$c = 1.3 * K *(\Delta H/\Delta L_o)^{0.38}$$

Here, “K” is a constant that depends on the insulation type. A 1.0 value for NUKON fiber is applied for the evaluation.

According to the Section 4.1.1 of the NUREG/CR-6874 (Reference [8]), there is a practical limit to the fiber bed compression whenever significant particulate is embedded in the fiber matrix. The particulate cannot be compressed beyond its granular density, referred to herein as the sludge density (e.g., ~65 lbm/ft3 for BWR suppression pool iron oxide corrosion products). Therefore, whenever the bed density reaches the following limit, further compression ceases.

$$\Delta L_m = \Delta L_0 \frac{C_f}{C_p}(\eta + 1)$$

Where:

C_f : the fabricate density of fibers

C_p : the sludge density of particulates

Each constituent of debris has a surface-to-volume ratio associated with it based on the characteristic shape of that debris type. For typical debris types, the following correlations are applied:

Cylindrically shaped debris : Sv = 4 / diameter
Spherically shaped debris : Sv = 6 / diameter
Flakes (flat plates) : Sv = 2 / thick

The following is a method for calculating the average surface to volume ratio for two different types of debris constituents.

$$Sv = SQRT [(Sv_1^{2}*v_1 + SV_2^{2}*v_2) / (v_1+v_2)]$$

Where v_1 and v_2 are the microscopic volumes of constituents “1” and “2,” respectively.

Clearly, this result can be extended to more than two such fiber species as follows:

$$Sv = SQRT [\Sigma(SVn2 * vn)/\Sigma(vn)]$$

Where the subscript “n” refers to the n^th^ constituent.

Based on the above methodology, the head loss due to a mixture of fibrous and particulate debris is calculated by applying the “NUREG/CR-6224 correlation software”. Calculated head loss results for the US-APWR strainer are provided in Table 3-6.

3.5.3 Thin Bed Effect

For conditions of fiber and particulate present in the post-LOCA containment pool, as the fiber bed is deposited on the strainer, particulate material will be trapped by the fiber, increasingly so as the fiber bed thickens. Once a fiber bed of approximately 1/8” thickness is formed, if there is sufficient particulate debris, a low permeability granular layer of debris on top of the fiber bed will be formed. The head loss associated with the accumulation of mostly particulate debris on thin fibrous beds can be quite high, greater than the head losses associated with much larger quantities of fiber and much thicker beds of debris. This apparently counterintuitive head loss phenomenon is known as the TBE.

The TBE is typically analyzed by assuming a fiber quantity sufficient to form a bed 1/8” thick is available and deposited on the strainer. The head loss of TBE is estimated using the same correlation described in the previous Section 3.5.2 and assuming that all particulate debris amounts are transported to the strainer including latent debris.

The head loss due to TBE is calculated by applying the “NUREG/CR-6224 correlation software”, and the calculation results of the US-APWR strainer are provided in Table 3-6.

3.5.4 Total Debris Head Loss

The head loss due to RMI, fibrous and particulate mixture debris bed was estimated, and summarized in Table 3-6. In addition to the head loss, the influence of chemical effect of the debris on the US-APWR must be considered. At the present time, the increase in head loss due to chemical effect is uncertain, but it was assumed conservatively and is included in the evaluation.

The conservatively assumed in increase in debris head loss due to chemical effect is added to the calculated debris head loss due to RMI, fibrous and particulate mixture debris, and the total debris head loss is shown in Table 3-7.

3.6 Net Positive Suction Head

3.6.1 System Operation

The US-APWR engineered safety features (ESF) include safety injection (SI) pumps and containment spray/residual heat removal (CS/RHR) pumps. These pumps are normally aligned to the refueling water storage pit (RWSP) inside the containment. Figure 3-5 shows a schematic flow diagram of ECC and CSS. The SI pumps are automatically initiated by the safety injection signal and the CS/RHR pumps are automatically initiated by the containment spray signal. These pumps take suction directly from the RWSP. Four ECC/CS strainers are installed in the RWSP and each ECC/CS strainer is for one of four trains.

3.6.2 NPSH Available Calculation

Net-positive suction head (NPSH) calculations were performed to confirm the ECCS and CS pump “NPSH available” is sufficient to provide the NPSH required.

3.6.2.1 Assumptions

In this NPSH available calculation, the most limiting conditions are assumed to be applicable to all events.

a) Single Failure

The SI pumps and CS/RHR pumps of the US-APWR consist of four trains and an ECC/CS strainer is installed for each train (e.g., one ECC/CS strainer is for one SI pump and one CS/RHR pump). Therefore, a single failure in other trains does not affect flow rate through the strainer.

Since the safety injection system configuration of the US-APWR is independent for each train, the failure of a single pump or a single emergency bus results in decreased head loss across the common sump screen. Therefore, such failures have positive effect on NPSH available.

The containment spray system has a common spray ring header. Therefore, if the number of operating pumps is smaller, the flow in any one pump is greater. The minimum number of operating CS/RHR pumps is two (one pump is assumed out of service, a second one is assumed to experience a single failure, and the remains two are operating).

Therefore, the most limiting single failure for sump screen flow rate is a single CS/RHR pump failure. In the NPSH calculation, the maximum pump flow rates are conservatively used which are greater than those in the case of a single failure.

b) Containment Pressure

For the minimum NPSH available calculation, no containment overpressure is credited (i.e., containment pressure is assumed to equal the saturation pressure corresponding to the sump water temperature).

c) Water Level

RWSP water level for NPSH available calculation is the minimum RWSP water level. The details of the calculation of minimum water level are given in Section 3.7. The water level used in NPSH available calculation includes a 5% uncertainty.

d) Head loss

Head loss calculations for NPSH available are prepared based on hydraulic models of the systems aligned to take suction from the RWSP. The system configurations of SI pump suction and CS/RHR pump suction are not changed during an accident. Therefore this system configuration results in the highest sump flow rate, which is used for sizing the ECC/CS strainers. The flow rate for the NPSH available calculation is conservatively based on the maximum pump flow rate. These calculations use Equations 3-5, 3-14 and 3-15 of Crane Technical Paper No. 410, “Flow of Fluids Through Valves, Fittings, and Pipe” (Reference [9]) to determine the head loss due to frictional resistance in the piping and line losses due to other components. The water temperature for head loss calculation (Pipe, fitting, and so on) is conservatively set as 32 deg F, which is the freezing point of water. The head loss used in NPSH calculation includes a 5% uncertainty.

e) Debris head loss

Debris head loss is used for NPSH available calculation. The details of the debris head loss computation are described in Section 3.5.

3.6.2.2 Calculation Results

The NPSH available is calculated based on the equation below;

$$NPSH_{available} = h_{statichead} - h_{lineloss} - h_{ECC\,/\,CSstrainerloss}$$

$h_{statichead}$	Static head (RWSP minimum water level – pump center elevation)
$h_{lineloss}$	Head loss (Suction piping and valve pressure loss)
$h_{ECC\,/\,CSstrainerloss}$	Debris head loss (Due to debris clogging and chemical effect)

For static head, the relationship between RWSP minimum water level and pump center elevation is shown in Figure 3-6. In this calculation, the water level is used 3.8’, which includes a minus 5% margin for an uncertainty.

The NPSH available for the SI pump and the CS/RHR pump are shown in Tables 3-8 and 3-9.

3.7 Upstream Effect

3.7.1 Hold-up Volumes

The evaluation of upstream effect is a review of the flow paths leading to the RWSP, identifying those flow paths which could result in blocking the return water that could challenge the RWSP minimum water level evaluation. The evaluation also includes identifying the hold-up volumes, such as recessed areas and enclosed rooms, for which trapped water will not return to the RWSP. The evaluation of the US-APWR was performed, and all of the hold-up volumes were taken account into the minimum water level calculation. The description of the US-APWR flow paths was discussed in the DCD Chapter 6, Section 6.2.1.1.2, and is summarized as follows:

“Figure 6.2.1-9 through Figure 6.2.1-15 also shows containment drainage paths into the RWSP. Piping is provided through several partitions above the RWSP where water could otherwise be trapped. In particular, piping that allows free communication and drainage is installed between the refueling cavity and the pressure equalizing chamber, as shown in Figure 6.2.1-9. These communication pipes are closed with a flange at both ends during refueling. Drain piping also is provided between the pressure equalizing chamber and the RWSP. Figure 6.2.1-16 and Figure 6.2.1-17 present the plan and sectional view of the RWSP, while Table 6.2.1-3 presents RWSP design and containment-related features.”

Figure 3-7 shows a schematic of containment spray/blowdown return pathways of the US-APWR, and is provided to supplement the information in the DCD. Containment spray water is showered on the operating floor, SG compartments, and refueling cavity. The water on the operating floor easily spills out from a number of large floor openings to the area downstairs. In addition, a number of floor drain funnels lead the spray water to bottom portion of the containment. The water sprayed into the SG compartments will easily reach to the bottom floor of the containment, because only the layered intermediate grating floors are installed inside the compartment. In the refueling cavity, there are two 8 inches drain pipe which are communicated to bottom portion of the containment. As discussed in Section 2, the use of RMI is maximized and it is quite unlikely that a large amount of fibrous debris will blow down on the cavity, and block the drain path.

In a LOCA, the blowdown water spills out from reactor coolant pipe located inside the secondary shield wall. Since four large personnel entrances leading into the secondary shield wall are provided, the debris will not clog these entrances. As a result, no choke points which may block the flow paths of return water are identified. Therefore, only the hold-up volumes may challenge the minimum water level of the RWSP.

The US-APWR hold-up volumes are categorized into two groups, “Return water on the way to the RWSP”, and “Ineffective pools”. The calculated values described in the DCD Table 6.2.1-3 *“RWSP Design Features”*. The followings are the definitions of the groups:

Return water on the ways to the RWSP

In a LOCA, the RWSP water returns from containment spray nozzle and broken pipe. The water on the way to the RWSP will decrease the initial RWSP water level. The following are the source of return water to the RWSP.

a. Containment spray water droplets and saturated steam (includes the empty spray header rings and pipes)
b. Condensate water on all of the containment surfaces (includes equipment, walls and ceiling, etc.)
c. Water stream on the containment floors (includes refueling cavity floor)

Ineffective pools

An ineffective pool is defined as a hold-up volume that entraps return water which will not contribute to recovering the RWSP water level. The following are considered as the US-APWR ineffective pools:

a. Reactor cavity
b. Containment recirculation air distribution chamber (includes ducts)
c. Containment reactor coolant drain pump room (includes containment drain sump)
d. Recessed pits in the refueling cavity

In addition to the above, a further hold-up volume was conservatively included, and assumed to be 90 m^3 usnig engineering judgement. The calculated hold-up volumes of the US-APWR are provided in Table 3-10.

3.7.2 Minimum Water Level

The minimum water level of the RWSP forms the basis for estimating pump water head in the NPSH evaluation, as discussed in Section 3.7. It was conservatively calculated as follows:

During normal operation, the RWSP contains 2300 (m^3) of borated water (the water volume from 0 (%) to 100 (%) water level), as shown in Figure 3-8. The RWSP allows the water evaporation and when the water surface reaches the 96 (%) water level, the makeup operation is activated and continued until 100 (%) water level is recovered. This level is defined as "below nominal water level" of the RWSP, and is used as the initial water level for the postulated accidents. In case of LBLOCA, the water mass in the accumulator tanks can contribute to recover the RWSP, but this source was conservatively disregarded in the calculation.

The minimum water level of the RWSP during a LOCA was calculated by subtracting the hold-up volume from the initial water volume in the RWSP. The minimum water level is calculated as shown in Figure 3-8, and it is determined that it will be settled at 4.5 feet above the RWSP floor. It was then conservatively set at 0.5 feet lower than the calculated level. The minimum water level of the US-APWR was therefore set at 4.0 feet above the RWSP floor, and this value was used in the NPSH evaluation.

3.8 Test Plan for Chemical Effect

The calculated head losses due to the fibrous and particulate mixture debris bed discussed in Section 3.6 were determined using the correlation given in NUREG/CR-6224, and used for the preliminary evaluation of the US-APWR strainer performance. Confirmatory testing is planned to identify the actual debris head loss, including chemical effect, in order to define the values for the design basis of the US-APWR. Prior to conduct the debris head loss testing, the characteristics of chemical precipitants which may be generated in the accidental environment of the US-APWR containment must be established. The following are the basic plan of upcoming chemical tests.

3.8.1 Test Objectives

This test plan addresses two (2) objectives:

a. Determine, characterize and quantify the chemical reaction products that may develop in a representative post-LOCA containment sump environment.
b. Determine and quantify any gelatinous material that develops during testing.

The evaluation of the data collected will be directed at determining if corrosion products form and/or if leaching of materials (from fiberglass, concrete, etc.) occurs in a representative post-accident sump fluid inventory, and characterizing and quantifying the corrosion products and leached solids to support the evaluation of their impact on post-accident strainer head loss. The test loop will be operated within a time-temperature-chemistry profile representative of PWR post-LOCA operation, except that the loop will be operated at a constant temperature.

3.8.2 Test Parameters

Tests will be conducted using justifiable proportions of non-metallic, metallic, and cementitious materials exposed to the warm, slightly basic pH liquid of the containment pool and spray environment. The test plan logic is to conduct testing with representative material surface areas and sump volumes and chemical constituents to provide test conditions simulating the post-LOCA sump environment.

3.8.3 Test Duration

Maximum duration of any test is limited to 30 days. Duration of subsequent test runs following the initial run will be determined after evaluating the results of the first run, and will consider establishing steady state conditions.

3.8.4 Sampling and Examination

Sampling shall be performed at such frequencies as are necessary to obtain the required information regarding the behavior of the test loop and to characterize the chemical reaction products.

A determination of the chemical constituency and compounds, size, density, specific surface area, and information relative to the microstructure of the material (crystalline or amorphous) shall be made.

Analyses of fluids shall be performed to characterize dissolved material in the test loop and the behavior of loop chemistry.

Sediment characterization will include, as appropriate and feasible, determining the mass and volume collected, identifying the constituents (e.g., fiberglass, latent particulate, precipitate, etc.), determining of density and specific surface area, establishing whether amorphous or crystalline, and determining the elemental composition and speciation.

3.9 Evaluation Summary

The US-APWR sump strainer performance was evaluated in accordance with the RG 1.82 Rev.3 requirements. The break selection, debris generation, and debris transport were analyzed to identity the potential debris which may reach to the strainers in the RWSP assuming a number of conservative considerations. The characteristics of potential debris were set, identified, and referred appropriately, and used in the debris head loss calculations, as well as the NPSH evaluation of vital pumps of the US-APWR.

The calculated head losses due to the estimated debris for the US-APWR were determined, but confirmatory test must be required because of the uncertainties involved. Confirmatory tests are planned to identify the actual debris head loss, evaluate the chemical effects, and define the values for the design basis of the US-APWR.

The chemical tests will be conducted through the end of March, 2009, and debris head loss testing will be conducted subsequently. The tests reports will be submitted to the NRC as the tests progress, and will be finally incorporated into this technical report atl the end of June, 2009.

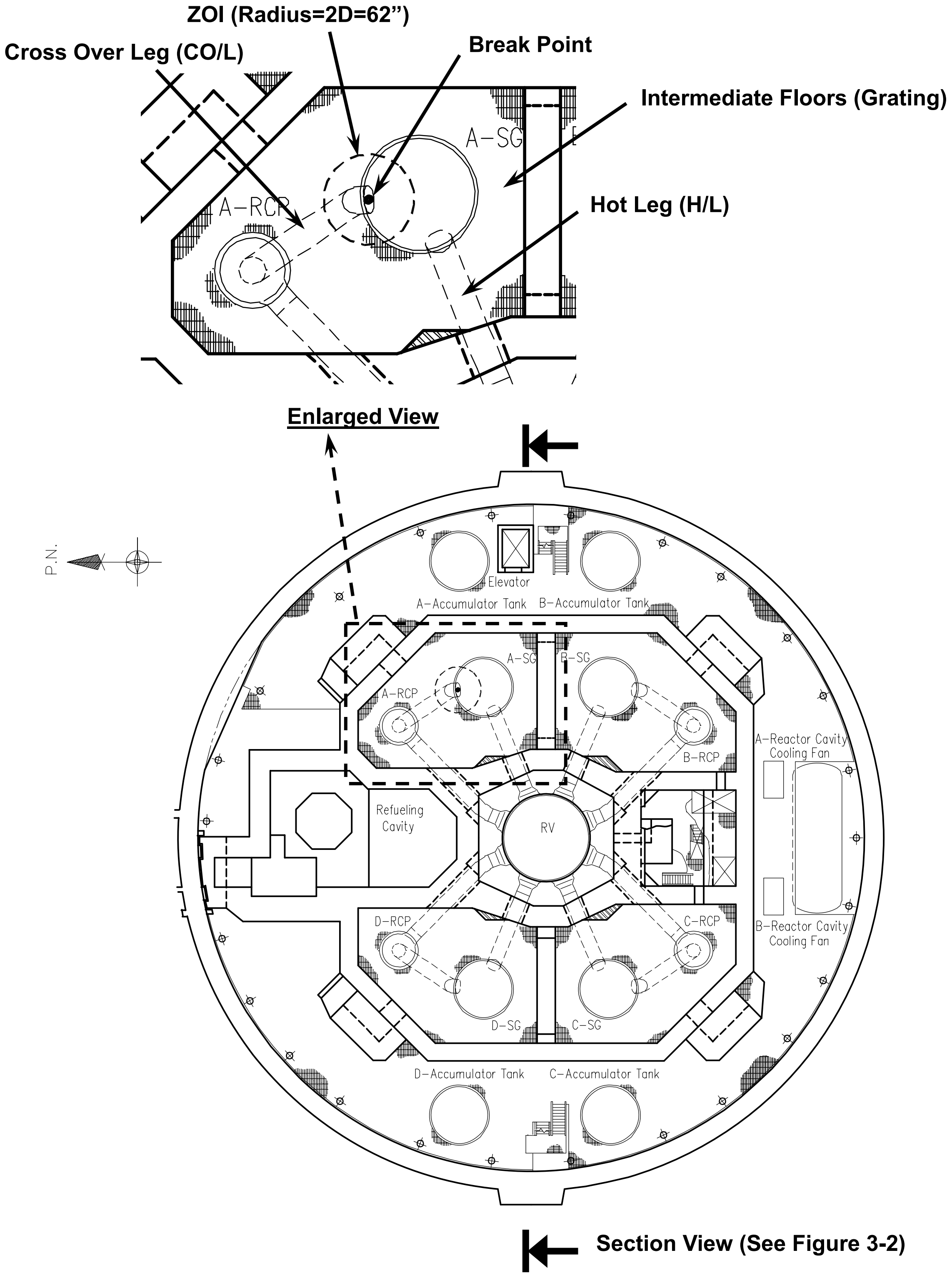


Figure 3-1 Plan View of Zone of Influence (RMI, L/D=2.0)

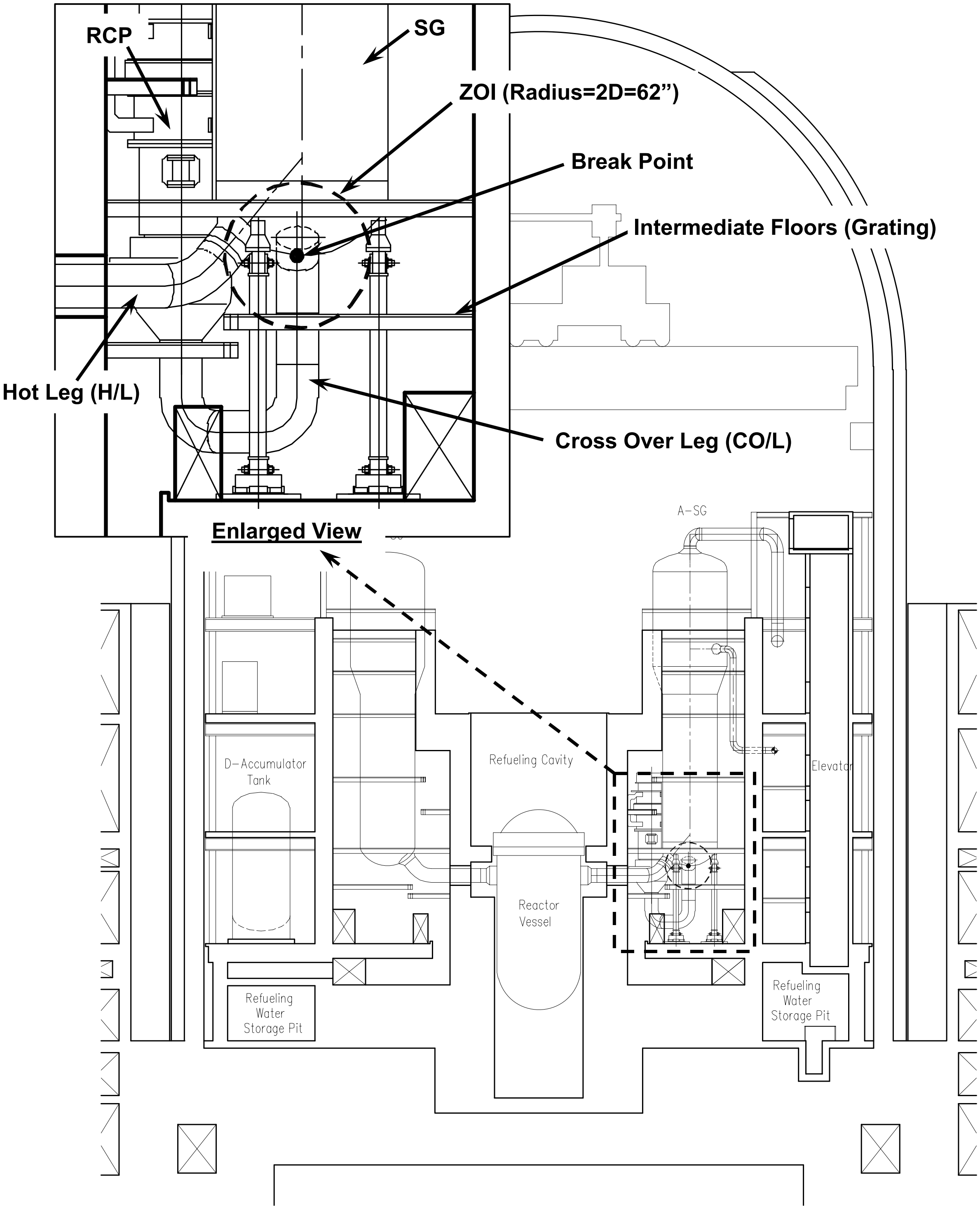
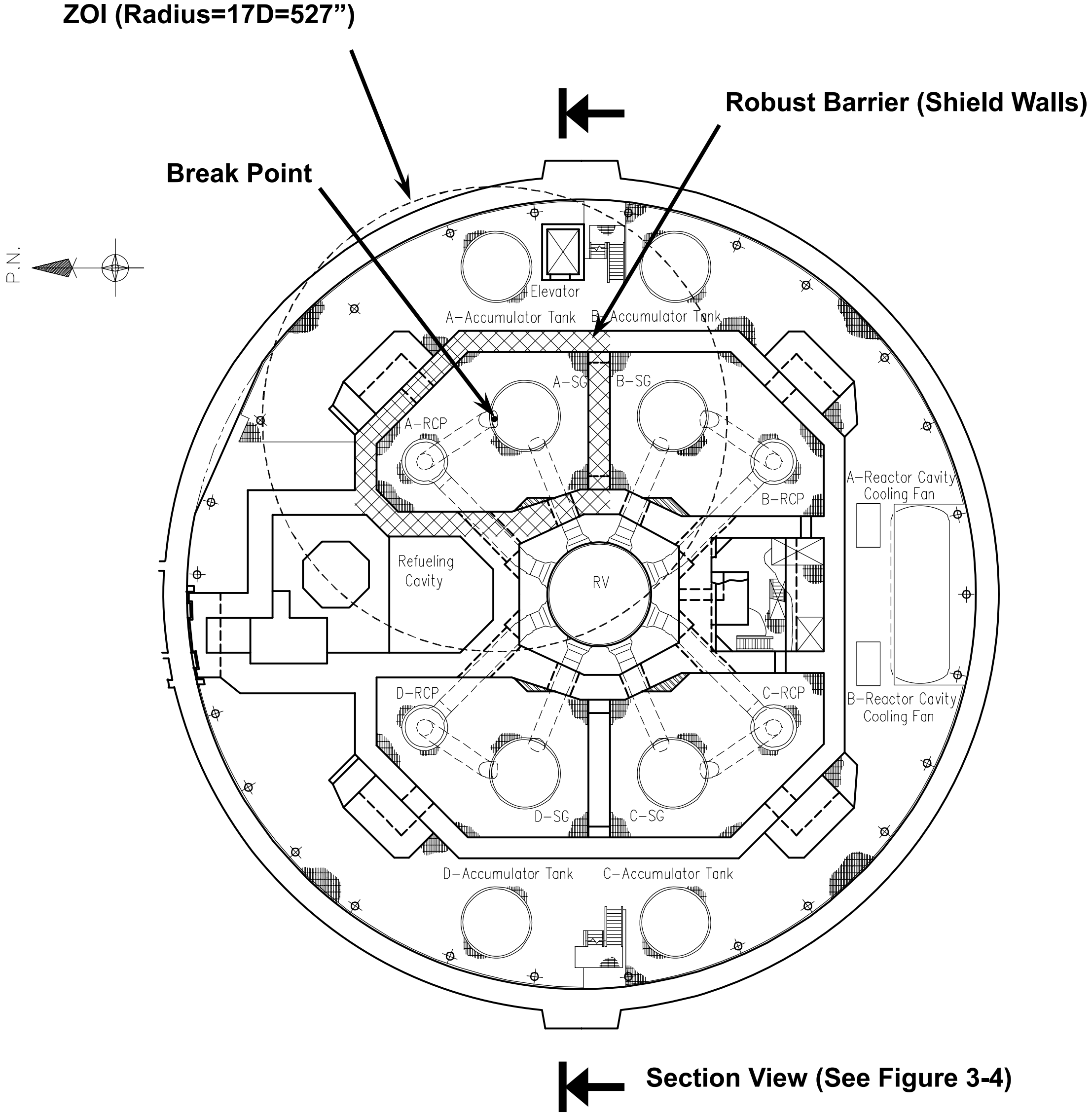


Figure 3-2 Section View of Zone of Influence (RMI, L/D=2.0)


ZOI (Radius=17D=527")

Robust Barrier (Shield Walls)

Break Point

Section View (See Figure 3-4)

Figure 3-3 Plan View of Zone of Influence (Nukon, L/D=17)

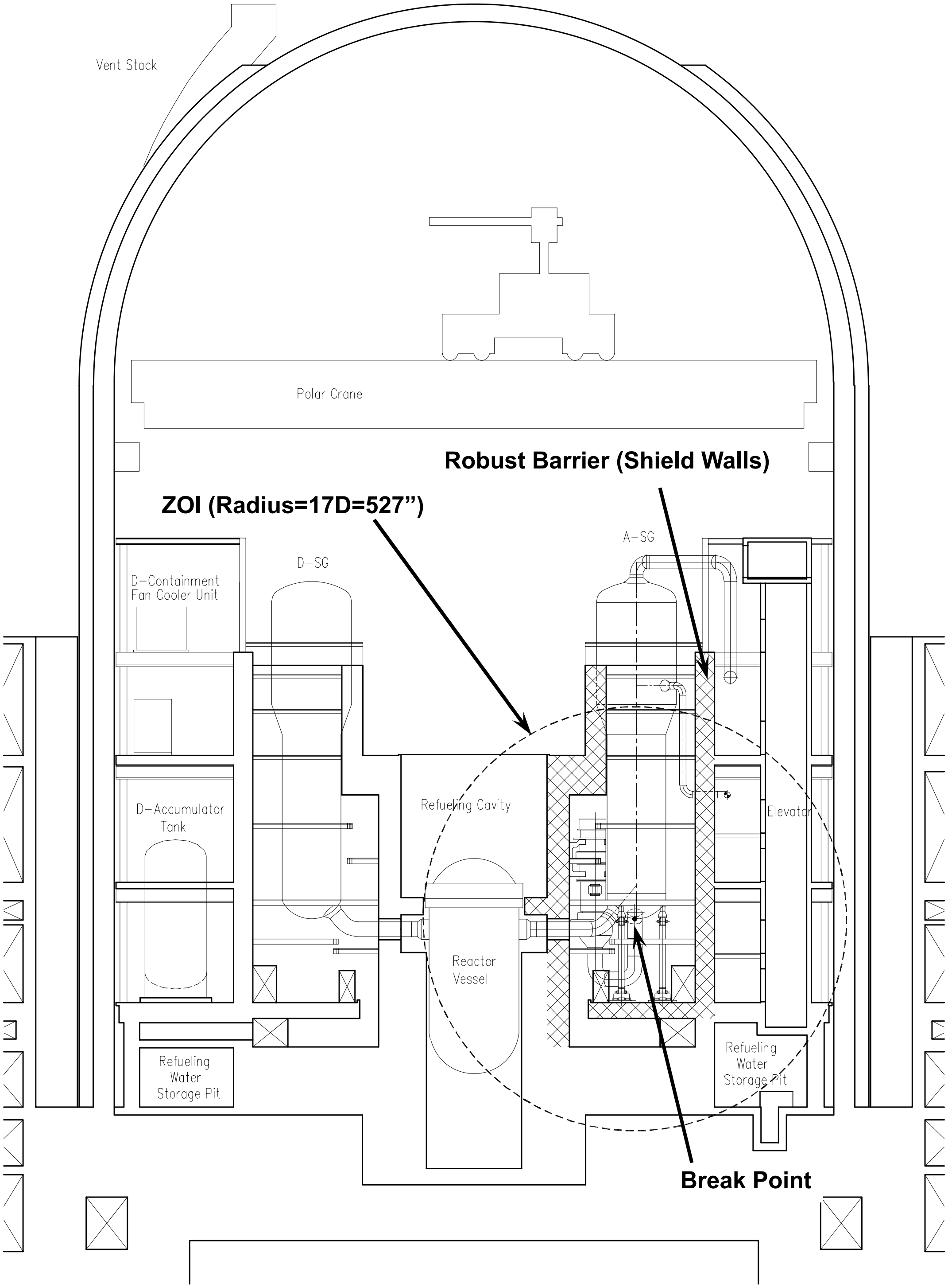


Figure 3-4 Section View of Zone of Influence (Nukon, L/D=17)

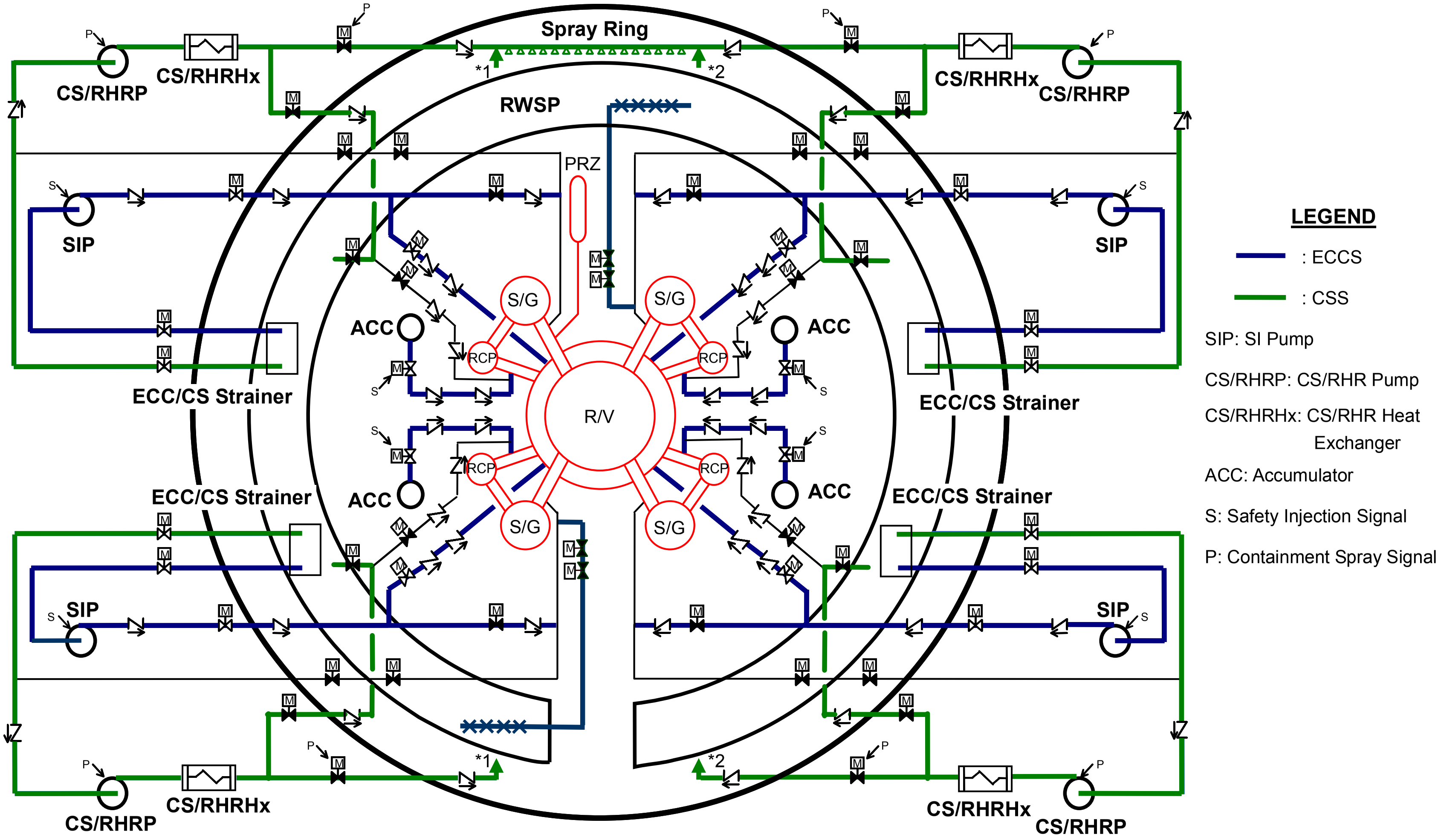


Figure 3-5 Schematic Flow Diagram of ECCS/CSS

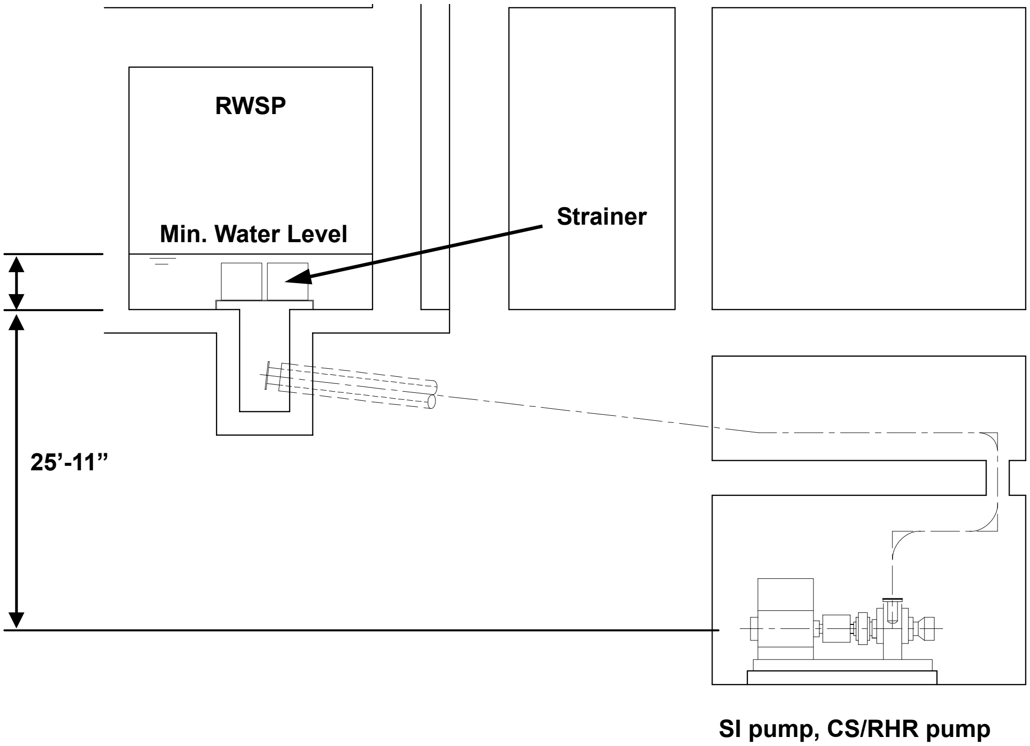


Figure 3-6 Elevation between Minimum Water Level and the Pumps

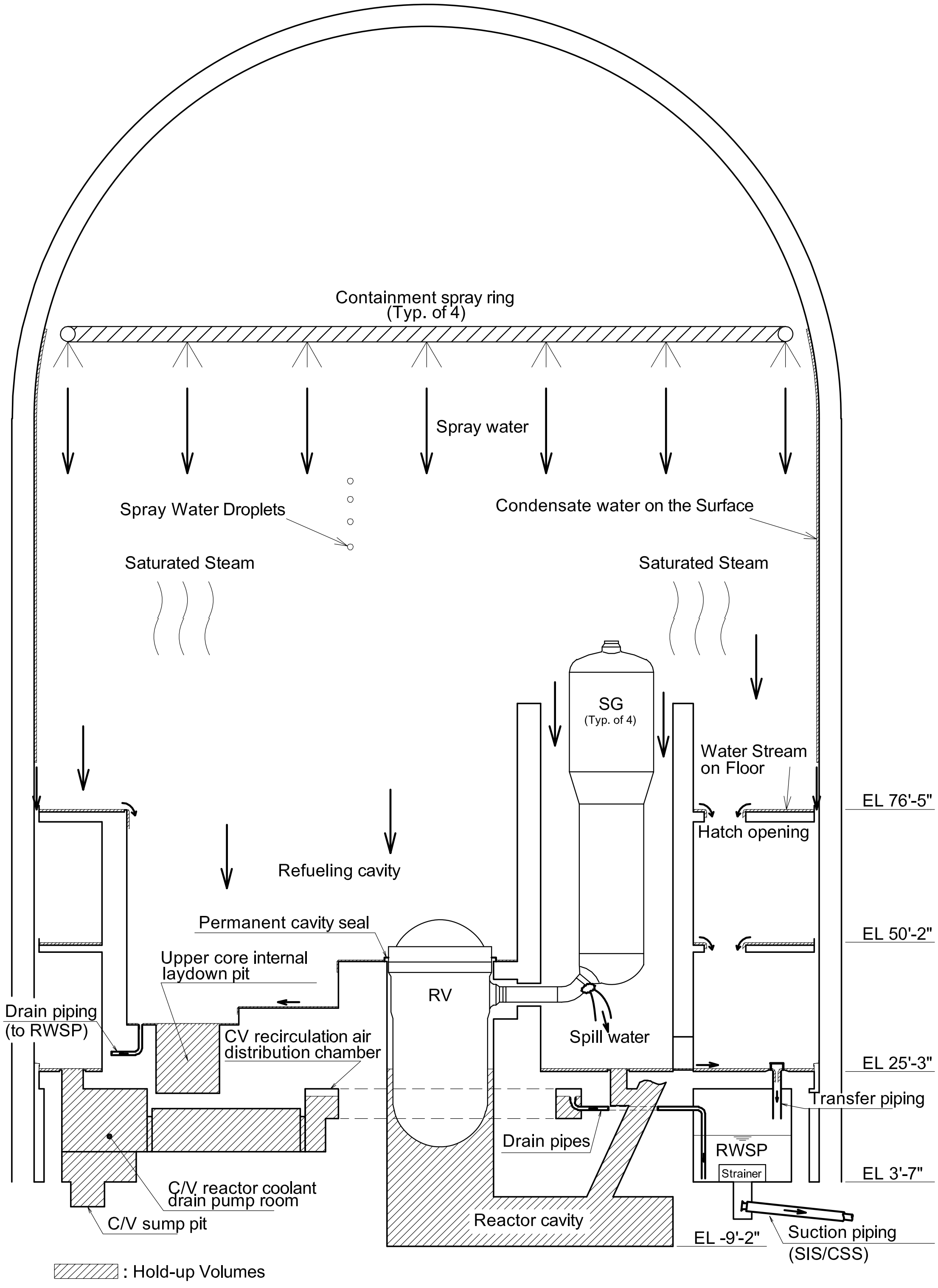


Figure 3-7 Schematic of Return Water and Hold-up Volumes

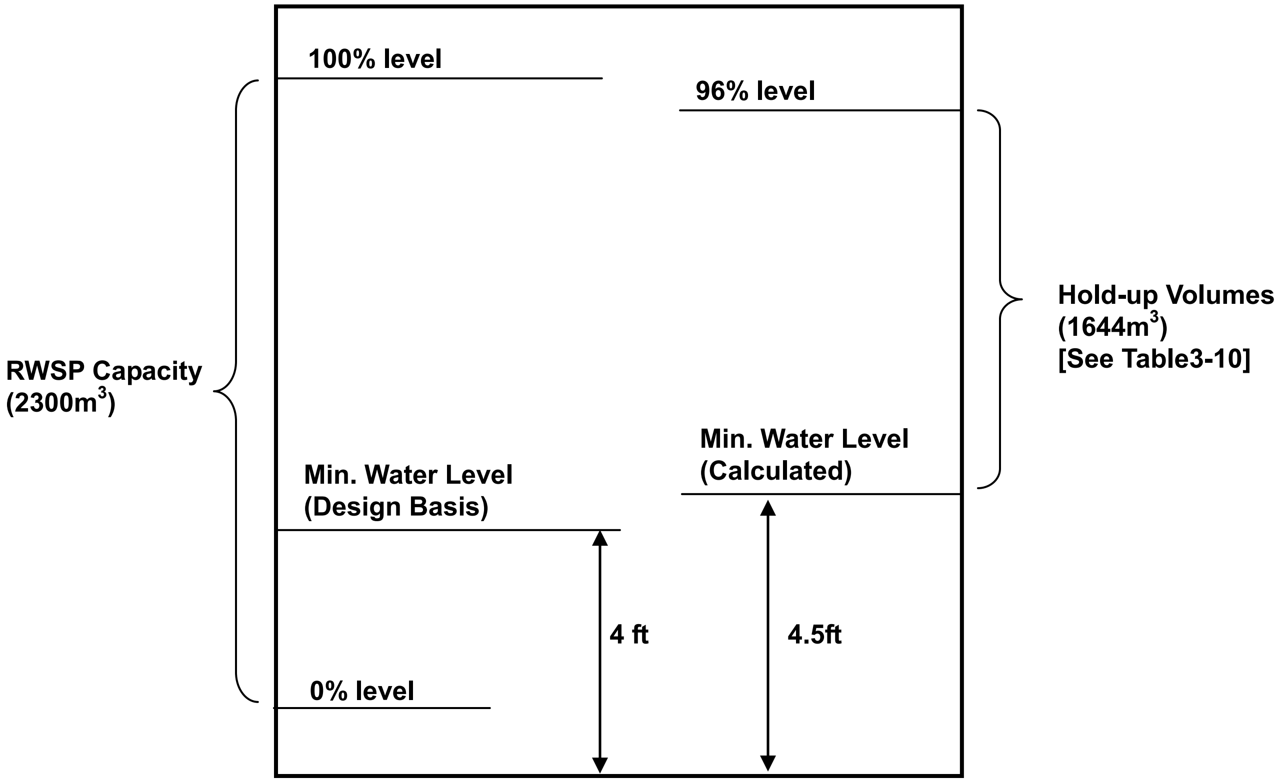


Figure 3-8 Minimum Water Level of the RWSP

Table 3-1 The US-APWR Postulated Break Pipe Lines

Pipe lines	Size	Location					
	Inner Diameter (in)	Inside secondary shield wall					Outside secondary shield wall
		SG compartment				PZR compartment	
		A	B	C	D		
Main coolant pipes	31	X	X	X	X		
PZR surge line	12.81		X				
Accumulator injection lines	11.19	X	X	X	X		
RHR pump inlet lines	8.5	X	X	X	X		
RHR pump outlet lines	6.81	X	X	X	X		
PZR spray line	5.19		X	X		X	
Direct Vessel Injection lines	3.44	X	X	X	X		
Charging line	3.44	X					
Let down line	2.62				X		
Safety injection (SI) lines	3.44	X	X	X	X		
PZR aux. spray line	2.62					X	
PZR safety valve inlet line	5.19					X	
PZR safety depressurizeation lines	6.81					X	
	5.19					X	
	3.44					X	
	2.62					X	
Main steam lines	14.31						X
Feed water lines	29.01	X	X	X	X		X

Table 3-2 Damage Pressure and Corresponding Volume-Equivalent Spherical ZOI Radii

Type	Destruction Pressure (psig)	ZOI Radius / Break Diameter
Transco RMI Darchem DARMET	114	2.0
Unjacketed Nukon, Jacketed Nukon with standard bands	6	17.0

Table 3-3 Location of Fibrous Insulation

Pipe lines	Size	Location					
	Diameter (in)	Inside secondary shield wall					Outside secondary shield wall
		SG compartment				PZR compartment	
		A	B	C	D		
SG blow down lines	3 4	X	X	X	X		X
RCP seal water lines	1	X	X	X	X		
CVCS excess let down lines	1	X					X

Table 3-4 Debris Generation

Type		Amount	
		English unit	Metric unit
RMI (Transco)		106 (ft^3) [foil surface area 11,442(ft^2)]	3.0 (m^3) [foil surface area 1063(m^2)]
Fibrous Insulation (Nukon)		106 (ft^3)	3.0 (m^3)
Coating (Epoxy)		1.8 (ft^3)	0.51 (m^3)
Latent Debris (200 lbm)	Fiber (15%)	30 (lbm)	-
	Particle (85%)	170 (lbm)	-

Table 3-5 Debris Characteristics

Description	Symbol	Values
RMI debris		
Inter-foil gap thickness	Kt	0.003 (ft)
Fibrous Insulation debris (Nukon)		
Diameter of fiber	D_{f1}	7 (μm)
Fabricate density	C_{f1}	2.4 (lbm/ft^3)
Material density	ρ_{f1}	159 (lbm/ft^3)
Specific surface volume	S_{vf1}	1.742 x 10^5 (ft^{-1})
Coating		
Diameter of particle	D_{p1}	10 (μm)
Sludge density	C_{p1}	19 (lbm/ft^3)
Material density	ρ_{p1}	94 (lbm/ft^3)
Specific surface volume	S_{vp1}	1.829 x 10^5 (ft^{-1})
Latent Debris (Fiber) Note		
Fabricate density	C_{f2}	Assumed same as to Nukon
Material density	ρ_{f2}	93.6 (bm/ft^3)
Specific surface volume	S_{vf2}	Assumed same as to Nukon
Latent Debris (Particulate) Note		
Sludge density	C_{p2}	75 (lbm/ft^3)
Material density	ρ_{p2}	168.6 (lbm/ft^3)
Specific surface volume	S_{vp2}	1.06 x 10^5 (ft^{-1})

Note: The characteristics of latent debris were recommended in the SE and referenced in NUREG/CR-6877 (Reference [7]).

Table 3-6 Debris Head Loss

RMI debris		Negligible [2.678x10^{-4} (ft)]
Mixture of fibrous and particulate debris	Maximum Combination	1.3 (ft)
	TBE (1/8” thick fiber)	1.3 (ft)

Table 3-7 Total Debris Head Loss

Head loss due to RMI, fibrous and particulate mixture debris	1.3 (ft)
Increasing head loss due to chemical effect debris	3.4 (ft) (Assumed)
Total debris head loss	4.7 (ft)

Table 3-8 SI Pump NPSH Evaluation

$h_{statichead}$	29.7 ft
$h_{lineloss}$	3.1 ft
$h_{ECC\,/\,CSstrainerloss}$	4.7 ft
NPSH available	21.9 ft
NPSH required	15.7 ft

Table 3-9 CS/RHR Pump NPSH Evaluation

$h_{statichead}$	29.7 ft
$h_{lineloss}$	7.1 ft
$h_{ECC\,/\,CSstrainerloss}$	4.7 ft
NPSH available	17.9 ft
NPSH required	16.4 ft

Table 3-10 Upstream Effect Hold-up Volumes

[1] Return water on the way to the RWSP	(m^3)
Containment spray droplets & saturated steam (including the empty spray header rings & pipes)	249.7
Condensate water on the various surfaces	85.0
Water stream on the floor (including reactor cavity floor)	185.0
Subtotal [1]	519.7 (approx. 137,000 gallons)
[2] Ineffective pools	
Reactor cavity	491.7
Containment recirculation air distribution chamber (Including ducts)	128.1
Containment reactor coolant drain pump room (Including containment drain sump)	343.5
Recessed pits in the refueling cavity	70.7
Additional hold-up volume	90.0
Subtotal [2]	1124.1 (Approx. 297,000 gallons)

4.0 DOWNSTREAM EFFECT

4.1 Downstream Effect (Outside Reactor Vessel)

The systems which take suction from RWSP sump are the safety injection system and the containment spray system. These systems include pumps, heat exchangers, valves, piping, fittings and other components. These components may be affected by debris that comes through the strainers. This section describes the evaluation of potential downstream effects outside the reactor vessel.

4.1.1 System Operation

The SI pumps are automatically initiated by the safety injection signal and supply boric acid water from the RWSP to the reactor vessel through direct vessel injection lines. Then SIS is realigned to shift the RCS injection from the direct vessel injection line to the hot leg injection line after a LOCA in order to preventi boron precipitation. Therefore, both injection lines are in the flow paths of the water through the ECC/CS strainers. Safety injection pump minimum flow lines are also in these flow paths, which are always used when the pumps are operating.

The CS/RHR pumps are automatically initiated by the containment spray signal and spray into the containment from the RWSP through the containment spray lines. Then, after the containment pressure is sufficiently decreased, the CSS is realigned to shift from the containment spray line to the CS/RHR pump full–flow test line to remove the heat from the containment. Therefore, both lines are in the flow paths of the water through the ECC/CS strainers. The CS/RHR pump minimum flow lines are also in these flow paths, which are always used when the pumps are operating.

4.1.2 Evaluation

The strainer hole size is 1/16”. Therefore, when the gap of the components is less than this value, the flow path may be blocked. Components that are in the flow paths during accidents are listed in Table 4-1.

The evaluation results for the potential clogging of each component are described below;

Pumps: most flow areas are sufficiently larger, so the potential of plugging by debris is very low.

Valves: The valve types that are used in the flow path during an accident are gate, check, globe and butterfly.

Gate valves

Gate valves are used full-open or full-close. In the US-APWR, gate valve sizes are above 4’’, so they have a sufficient flow area. Therefore the potential of gate valve plugging is very low.

Check valves

Check valves in the US-APWR are used with sufficient flow rate, and check valve sizes are above 4’’. Therefore the potential of check valve plugging is very low.

Globe valves

Globe valves may be used for throttling. When an expected difference pressure of globe valve is larger, the gap between valve body and seat may be very small. In the US-APWR design, the expected differential pressure is normally achieved by a combination of valve and orifice settings. Therefore the gap can be controlled not to be too small. Moreover, since the high head safety injection system of the US-APWR is designed to be completely independent, each train does not affect the other trains. So, ineffective injection water does not need to be considered. This means that high injection line resistance is also not needed. Therefore, the expected differential pressure of globe valves and orifices are not too large and the gap is not likely to be small.

Butterfly valves

Butterfly valves in the US-APWR are used at the outlet of CS/RHR heat exchanger. These valves are used full open and valve sizes are 8’’. Therefore the potential of butterfly valve plugging is very low.

Heat exchangers: the smallest portion of the CS/RHR heat exchanger is a tube. The tube size is 3/4’’ and is sufficiently larger than the strainer hole size. Therefore the potential of the CS/RHR heat exchanger plugging is very low.

Orifice: the hole diameter of an orifice is determined by the expected differential pressure. As described for globe valves, since the expected differential pressure of orifices is not too large and the hole is not too small, the potential of orifices plugging is very low.

Spray Nozzles: The containment spray nozzle has an inlet orifice 0.375” in diameter. This orifice is the smallest portion of spray nozzle and is larger than the strainer hole size. Therefore the potential of spray nozzle plugging is very low.

Instrumentation tubing: These lines are water-solid and designed to remain water-solid. This design precludes the direct introduction of debris-laden fluid into the instrumentation tubing. Therefore, the potential of instrumentation tubing plugging is very low.

Piping: Pipe diameters are sufficiently larger than the strainer hole size. Therefore the potential of piping plugging is very low.

Small particles of debris that come through the ECC/CS strainers may adversely affect components experience in the downstream of the strainers. Some parts of components such as valves or pumps may wear by contact with debris particles. This means that the components may be affected by particles. Therefore, the effects of the small particles should be evaluated

In the US-APWR design, the amount of the particle debris is expected to be small since compartment walls are consist of steel concrete which surfaces are covered by steel mold plate. This design decreases amount of concrete sludge during accidents. Materials that com in contact with water through the strainers have high resistance to erosion. Therefore, the potential for asverse effects from debris particles is very low.

4.2 Downstream Effect (Inside Reactor Vessel)

4.2.1 Blockage of Core Inlet

The following sequence is the US-APWR core cooling path flows in the reactor vessel downstream of the sump strainer. Cooling water will:

1. Come in from ECCS nozzle
2. Pass through the downcomer which is annulus between the reactor vessel and the core barrel
3. Pass through the lower plenum
4. Pass through the flow holes of the lower core support plate
5. Pass through the fuel assemblies
6. Pass through the holes of the upper core plate
7. Flows out from outlet nozzle

The smallest flow in the core internals is that of the flow holes of the lower core support plate whose size is [ ]The flow hole of the bottom nozzle in the fuel assembly is [ ]This is the narrowest gap downstream of the strainer to core inlet, and dictates that the nominal diameter of the strainer holes shall be sufficiently smaller than the gap.[ ]percent margin was considered to limit the debris which may pass through the gap, and no larger than 0.071” (1.8mm) of debris are blocked at the strainer. Finally, the industry standard perforate plate with 1/16” (1.59mm) was selected to the US-APWR strainer specification.

The flow hole of the lower core support plate is over [ ]times the size of the strainer holes. Therefore it is not necessary to consider piling up the downstream debris at any flow paths in the reactor internals. The flow hole of the fuel assembly bottom nozzle is[ ]times the size of of the strainer holes. Therefore, it is quite unlikely that the downstream debris may pile up at the fuel assembly bottom nozzle.

4.2.2 Trapping Debris in Fuel Assemblies

Debris passing through the flow holes of the bottom nozzle is interrupted by the bottom grid spacer in the fuel assembly. Since the debris passing through the strainer and the bottom nozzle is very small, most of the debris can flow out through clearances among adjacent fuel assemblies or inside the grid spacer. Thus, a small remaining amount of debris may be trapped by springs of the grid spacer.

The trapped debris is built up to about an inch height in the grid spacer, because the spring capturing the debris is located in the center of the grid spacer and has approximately two inches height. Such built up debris does not have significant influence on cooling of the fuel rod cladding at around the bottom grid spacer, because the corresponding region of the US-APWR fuel rod is at the lower plenum with no heat generation.

There is possibility that the debris passing through the bottom grid spacer will be trapped by the grid spacers at an upper elevation. Even if it happens, the channel closure by the locally built-up debris is less significant for core cooling in general, because heat removal is achieved by the coolant flow which can be supplied from such channels as exist among the fuel assemblies.

4.2.3 Boric Acid Precipitation

The US-APWR design uses boron as a core reactor reactivity control method, and there is a procedure that instructs the operators to switch operating DVI lines over to the hot leg injection line (simultaneous reactor vessel and hot leg injection) no sooner than about four (4) hours after the postulated large LOCA to prevent the core region boric acid concentration from reaching the precipitation point. The switchover time is determined by a simplified method, as described in the DCD Chapter 15, based on assumptions regarding mixing in the reactor vessel.

The debris ingested into the core region through the strainers may have some impact on the assumed mixing volume for the evaluation of boric acid concentration during the post-LOCA long term cooling. The debris in the coolant in the reactor vessel would displace water volume that would otherwise dilute the boric acid in the core region. However, the displaced volume of debris would be a small fraction of the liquid mixing volume used for the evaluation of US-APWR boric acid concentration, which is of the order of many hundreds of cubic feet. Therefore, debris ingested into the reactor vessel would not significantly affect the estimation of boric acid concentration in the core region.

4.2.4 Hot Leg Injection

The US-APWR design adopts ECCS hot leg injection no sooner than about four (4) hours after occurrence of the postulated LBLOCA. At this switchover time, the coolant in the RWSP is expected to have been circulating through the ECCS and CSS several times. Therefore, particulate and fibrous debris, which is generated by the initial RCS break flow and CS water and then transferred to the RWSP, is expected to be depleted either by capture on the strainer or by settle-out in low flow rate regions, such as the lower plenum. Thus, the amount of debris injected during the hot leg injection mode is expected to be small enough that the core cooling is not significantly affected by the debris.

Table 4-1 Components List in the Flow Path during an Accident

Components	Remark
Pumps	
SIS-RPP-001A,B,C,D	Multi-stage centrifugal type
RHS-RPP-001A,B,C,D	Centrifugal type
Heat Exchangers	
RHS-RHX-001A,B,C,D	Shell & tube type
Valves	
SIS-MOV-001A,B,C,D	Gate, 10”
SIS-VLV-004A,B,C,D	Check, 4”
SIS-MOV-009A,B,C,D	Gate, 4”
SIS-VLV-010A,B,C,D	Check, 4”
SIS-MOV-011A,B,C,D	Globe, 4”
SIS-VLV-012A,B,C,D	Check, 4”
SIS-VLV-013A,B,C,D	Check, 4”
SIS-MOV-014A,B,C,D	Globe, 4”
SIS-VLV-015A,B,C,D	Check, 4”
SIS-VLV-023A,B,C,D	Globe, 2”
CSS-MOV-001A,B,C,D	Gate, 14”
CSS-VLV-002A,B,C,D	Gate, 10”
CSS-MOV-004A,B,C,D	Gate, 8”
CSS-VLV-005A,B,C,D	Check, 8”
RHS-VLV-004A,B,C,D	Check, 16”
RHS-VLV-013A,B,C,D	Globe, 3”
RHS-HCV-603	Butterfly, 8”
RHS-HCV-633	Butterfly, 8”
RHS-MOV-021A,B,C,D	Gate, 8”
RHS-VLV-022A,B,C,D	Check, 8”
RHS-MOV-025A,B,C,D	Globe, 8”
Orifice	
SI pump outlet flow instrument orifice	
SI pump minimum flow orifice	
Direct vessel injection line orifice	
Hot leg injection line orifice	
CS/RHR pump outlet flow instrument orifice	
CS/RHR pump minimum flow instrument orifice	
CS/RHR pump minimum flow line orifice	
Containment spray ring orifice	
Spray Nozzle	
Containment Spray Nozzle	Orifice size 0.375 in.

5.0 CONCLUSION

This technical report describes the design and the evaluation of the US-APWR sump strainer.

The US-APWR sump strainer design is intended to consistent with the requirements in RG 1.82 Rev.3. The calculated head losses due to the estimated debris of the US-APWR were conservatively determined. The ECCS and CS pump NPSH available is sufficient to provide the NPSH required. The downstream effects of debris flow through the strainers are evaluated. Confirmatory tests are planned to identify the actual debris head loss, evaluate chemical effects, and define the values for the design basis of the US-APWR. The tests report will be incorporated into this technical report at the end of June, 2009.

6.0 REFERENCES

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