ENCLOSURE 2

APP-GW-GLR-079-NS, Revision 0

"AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA"

Technical Report 26

Public Version

Redacted version of Enclosure 1 with sensitive unclassified non-safeguards information related to the physical protection of an AP1000 Nuclear Plant withheld from public disclosure pursuant to 10 CFR 2.390(d)

AP1000 DOCUMENT COVER SHEET

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TITLE: **AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA**

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AP1000 Standard Combined License Technical Report

AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA

Revision 0

This document has sensitive unclassified non-safeguards information (SUNSI) related to the physical protection of an AP1000 Nuclear Plant redacted pursuant to 10 CFR 2.390(d).

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INTRODUCTION

This technical report provides the information for closing the following Combined Operating License (COL) Information Item from APP-GW-GL-700, AP1000 Design Control Document (DCD), Revision 15:

COL Information Item	Design Control Document Section and Title	Description
6.3-2 Verification of Containment Resident Particulate Debris Characteristics	6.3.8.2 Verification of Water Sources for Long Term Recirculation Cooling Following a LOCA	The Combined License applicants referencing the AP1000 will perform an evaluation consistent with Regulatory Guide 1.82, revision 3, and subsequently approved NRC guidance, to demonstrate that adequate long-term core cooling is available considering debris resulting from a LOCA together with debris that exists before a LOCA. As discussed in DCD subsection 6.3.2.2.7.1, a LOCA in the AP1000 does not generate fibrous debris due to damage to insulation or other materials included in the AP1000 design. The evaluation will consider resident fibers and particles that could be present considering the plant design, location, and containment cleanliness program. The determination of the characteristics of such resident debris will be based on sample measurements from operating plants. The evaluation will also consider the potential for the generation of chemical debris (precipitants). The potential to generate such debris will be determined considering the materials used inside the AP1000 containment, the post-accident water chemistry of the AP1000, and the applicable research/testing.

In addition, this technical report presents an additional requirement to COL Information Item 6.3-1, shown here as it currently appears in DCD Revision 15:

COL Information Item	Design Control Document Section and Title	Description
6.3-1 Containment Cleanliness Program	6.3.8.1 Containment Cleanliness Program	The Combined License applicants referencing the AP1000 will address preparation of a program to limit the amount of debris that might be left in the containment following refueling and maintenance outages. The cleanliness program will limit the storage of outage materials (such as temporary scaffolding and tools) inside containment during power operation consistent with COL item 6.3.8.2.

The additional requirement is that the containment cleanliness program must provide cleanliness conditions consistent with the conditions used for this evaluation.

Based on this report, the NRC should consider the above COL Information Item closure to be acceptable and generally applicable to COL applications referencing the AP1000 design certification.

TECHNICAL BACKGROUND

SUMMARY

The AP1000 Nuclear Power Plant uses natural recirculation for cooling the core following a loss of coolant accident (LOCA). This capability of the AP1000 plant is presented in the DCD.

Screens are provided in strategic areas of the plant to remove debris that might migrate with the water in containment and adversely affect core cooling. Accordingly, it must be assured that the screens themselves are not susceptible to plugging.

This technical report evaluates the potential for debris to plug the AP1000 screens consistent with Regulatory Guide 1.82 Revision 3 (Reference 1) and subsequently issued Nuclear Regulatory Commission (NRC) guidance. The evaluation considers the various potential contributors to screen plugging. It considers debris that could be produced by a LOCA as well as resident fibers and particles that could be present in containment prior to the LOCA. It considers the AP1000 containment design, equipment locations, and containment cleanliness program. The evaluation uses debris characteristics based on sample measurements from operating plants and evaluates the generation of chemical precipitants considering materials used inside the AP1000 containment, the post-accident water chemistry, and applicable research and testing. This report shows that the AP1000 screen designs are acceptable.

This technical background section has two major subsections. The first subsection describes the changes to the AP1000 screen designs. The second subsection provides the post-LOCA screen performance evaluation.

AP1000 SCREEN DESIGN

The AP1000 has two Containment Recirculation Screens and two In Containment Refueling Water Storage Tank (IRWST) Screens. Consistent with the response of the nuclear industry to NRC guidance on the evaluation of sump screens, the AP1000 screen sizes have been made significantly larger. This increase is judged to be prudent because of the standardized approach for the AP1000 design, the potential for additional industry testing and regulatory guidance, and the reduced impact of incorporating larger screens at this time. Table 1 shows the current and revised screen sizes for AP1000. The total size of each screen type is actually the sum of two screens of each type.

Table 1: Current and Revised Screen Sizes for AP1000

Screen Type	Current Total Size (ft^2)	Revised Total Size (ft^2)
Containment Recirculation	280	5000
IRWST	280	1000

Although the above sizes for each screen type are different, the sizes are consistent with the potential total amounts of debris each screen type might experience during a LOCA. The debris loading per square foot on each of the IRWST Screens is approximately the same as the loading on each of the Containment Recirculation Screens. The IRWST Screens would see significantly less total debris because the IRWST is closed except for two 4 inch gutter drain inlet lines. The water sources feeding these gutters are not subject to heavy debris loading from postulated break debris or latent containment debris. These larger screen sizes and their designs also eliminate the need for trash racks in front of the screens.

The following sections describe the AP1000 screens. The actual screen designs will have complex geometries such as folded pockets, stacked discs, etc. The specific screens used in the AP1000 will depend upon the screen vendor selected.

Containment Recirculation Screens

The current Containment Recirculation Screens are shown in DCD Revision 15 Figures 6.3-8 and 6.3-9. Attachment A shows the current and revised screen arrangements. The revised Containment Recirculation Screens occupy the wall in the eastern loop compartment that is adjacent to the reactor vessel wall. This location allows for better utilization of space in the loop compartment in addition to providing a much larger total screen area. The two Containment Recirculation Screens are located next to each other and are interconnected by an opening at their interfacing ends. The opposite ends of the screens are connected to plenums, one directly and one through a cross-over pipe. Each plenum has two suction lines which are connected to redundant Passive Core Cooling System (PXS) direct vessel injection (DVI) lines. This arrangement allows either PXS sub system to use the full area of both screens in the unlikely event that the suction lines on either system fail to open. Each plenum has a removable panel to allow testing of the check valves during refueling outages. In addition, the removable panel simplifies the connection of temporary piping to each suction line for pre-operational flow testing.

IRWST Screens

The current IRWST Screens are shown in DCD Revision 15 Figures 6.3-6 and 6.3-7. Attachment A shows the current and revised IRWST Screen arrangements. The revised IRWST Screens are along the wall above and behind the IRWST sumps. The screens are connected to a plenum that feeds the sumps in the IRWST. The sumps are enlarged slightly to allow access to the sump for inspection and for pre-operational testing without disassembly of the screen. This enlarged portion of the sump is covered to prevent screen bypass. This configuration provides 500 ft^2 of screen area for each sump pit.

AP1000 POST-LOCA SCREEN PERFORMANCE EVALUATION

Introduction

The AP1000 containment building is designed both to contain radioactive material releases and to facilitate long term core cooling in the event of a LOCA. Water discharged from a break is collected in the lower portion of the containment for recirculation by the PXS back to the core as described in DCD Section 6.3.2.1.3. The AP1000 containment sump screens protect the flow path and components of the PXS from debris that is generated by a postulated pipe break and any debris that is being transported in the recirculating water.

The NRC identified its concern regarding maintaining adequate long-term core cooling in Generic Safety Issue (GSI) 191 post-accident containment sump performance. Generic Letter (GL) 2004-02 (Reference

2), issued in September 2004, identified actions that utilities must take to address the sump blockage issue. The NRC position is that plants must be able to demonstrate that debris transported to the sump screen after a LOCA will not lead to unacceptable head loss for the recirculating flow. For the AP1000, this requirement is interpreted as demonstrating that debris transported to recirculating screens will not significantly impede flow through the PXS and will not adversely affect the long-term operation of the PXS.

Applicability to the AP1000 Design

The AP1000 design minimizes the potential for a LOCA to generate debris that might challenge the recirculation flow path:

- Because passive safety systems are used and there are no safety-related containment spray systems, the recirculation flow velocities are low thus minimizing the potential for debris transport.
- Metal reflective insulation (MRI), also called reflective metal insulation (RMI), is used on components that may be subjected to direct jet impingement loads; MRI is not transported to the AP1000 Containment Recirculation Screens with these low flow rates. As a result, there is no fibrous debris generated by the LOCA blowdown.
- Other insulation inside containment outside the zone of influence is jacketed or not submerged.
- Protective overhangs guard the Containment Recirculation Screens against coatings and other debris from falling onto or just in front of the Containment Recirculation Screens and being transported to the screens.
- Screen area is exceptionally large to provide for the collection of debris on the screens without impacting recirculation flow.

Two sources of potential debris are therefore evaluated for impact to the AP1000 recirculation flow path. These sources are:

1. Latent containment debris. Latent containment debris, or resident containment debris as it is sometimes called, is dirt, dust, lint and other miscellaneous materials that might be present inside containment at the initiation of a LOCA. The concern is that latent debris might be present in large enough quantities to collect on screen-like surfaces and inhibit flow through them.

2. Post-accident chemical effects. Post-accident chemical effects are the result of containment sump fluid reacting chemically with materials inside containment and producing chemical products (precipitants). The concern is that chemical products might be generated in sufficient quantities to collect on screen-like surfaces (or on fiber beds on screen-like surfaces) and challenge their ability to pass flow.

The following is an evaluation of both the latent containment debris and chemical products that may be present inside the AP1000 containment in the unlikely event of a LOCA, and an assessment of their impact on the recirculation flow path performance.

Evaluation Approach

The evaluation was performed in three steps:

1. The amount of latent containment debris that might be inside the AP1000 containment and transported to screens was evaluated. The evaluation used latent debris information collected

from walkdowns of existing Pressurized Water Reactor (PWR) containment buildings and the AP1000 containment design features to estimate latent debris loading for the AP1000. The amount of latent debris that might be transported to the AP1000 screens was also determined for different break locations.

2. The post-accident chemical products were estimated using a tool generated by the PWR Owners Group and design features of the AP1000.

3. The resulting head loss from the transport and collection of latent debris and post-accident chemical products on AP1000 recirculation flow paths was evaluated using a head-loss code obtained from the NRC.

The following summarizes the evaluations performed for each of the above steps.

Latent Containment Debris Evaluation

The purpose of this evaluation was to estimate the amount of latent debris found on surface areas in the AP1000 containment building as described in NEI 02-01 (Reference 3) and to determine how much of that debris would be transported to each set of AP1000 screens. Information collected from the walkdown of several current PWR containments was used as a basis for this evaluation.

The identification of containment areas that potentially contribute debris to the recirculation flow stream in the AP1000 following a LOCA was performed to be consistent with the applicable guidance of Reference 1 and the relevant aspects of COL Information Item 6.3-2. The applicable Reference 1 guidance and COL Information Items state that the evaluation must include:

- Specific consideration of "resident" debris - both fiber-form and particulate debris that accumulates on surfaces during plant construction, testing, and operations.
- The determination of the characteristics of this "resident" debris based on sample measurements taken in operating plants.
- The potential for the generation of chemical debris (precipitants).
- A containment cleanliness program that limits the types and amounts of resident debris in AP1000 operating plants. This report adds that the containment cleanliness program must limit resident debris to be consistent with this evaluation.

Containment in existing operating plants and in AP1000 was categorized into four general types of surfaces:

1. Horizontal surface areas
2. Walls
3. Equipment
4. Piping

Debris loading rates for each of these surfaces in AP1000 were established based on actual debris samples removed from similar surfaces in existing operating plants and visual observations during operating plant walkdowns. The debris loading in each area of AP1000 containment was established by multiplying the debris loading rate for that surface type times its surface area. The debris loading rates used for this evaluation are therefore based on the assumption that the AP1000 owner maintains containment cleanliness consistently with the operating PWR plants sampled.

Using actual debris samples removed from existing operating plants and visual observations during operating plant walkdowns, the types of latent containment debris and their relative volumes used in this evaluation are:

- Particulate material: approximately 85% of the total volume; assumed to be mostly dirt, welding slag, rust and grindings
- Coatings: approximately 5% of the total volume; assumed to be paints
- Fiber: approximately 10% of the total volume; assumed to be dust, fabric, and insulation.

Note that as mentioned above, the AP1000 Containment Recirculation Screens have protective overhangs to guard against coatings and other debris falling onto or just in front of the Containment Recirculation Screens. The overhangs are sufficiently large and the recirculation flow velocities sufficiently low that zinc coatings or the higher density epoxy coatings used in the AP1000 will settle out of the recirculating water before getting to the screen. DCD section 6.1.2.1.5 discusses the use of higher density coatings in the AP1000. For additional conservatism, the latent containment debris is assumed to include the coatings debris found in the operating plant walkdown data.

Because AP1000 uses significantly less fiberglass and other fibrous insulation inside containment, it is expected that the AP1000 latent containment debris would include less insulation debris. Again for conservatism, the latent containment debris in AP1000 is assumed to include the insulation debris found in the operating plant walkdown data.

Based on the above estimated debris volumes and types in current PWR containments, an estimate of the mass percentage of each debris type was made for the AP1000 containment.

Debris present on the various containment surfaces and components can be transported within the AP1000 containment by three different mechanisms: immersion in a pool of slowly-moving water, jetting of steam/water mixtures expelled through the break, and wetting from liquid drops falling from the containment dome during passive containment system (PCS) operation. For different postulated break locations, the total mass of latent containment debris divides into three categories: debris that can migrate to the Containment Recirculation Screens, debris that can migrate to the IRWST Screens, and debris that does not transport to either set of screens. For this evaluation, the debris that can migrate to either set of screens is considered. It is noted that the Westinghouse AP1000 design differs from the current PWR designs in that there is no safety-related containment spray system.

To assess the effects of differing break locations on the distribution of the total mass of debris between the three categories, three different accident scenarios were considered:

1. A loop compartment break, assumed to be a DVI line break at the reactor vessel. This break location is typical of primary system breaks with respect to the amount of debris that could be transported.
2. A break in the automatic depressurization system (ADS) stage 1, 2, 3 lines near the top of the pressurizer. This break produces the maximum debris for the IRWST Screens.
3. A break on the inlet line of a core makeup tank (CMT). This break produces the maximum debris for the Containment Recirculation Screens because water is assumed to flow down the CMT and into a PXS room.

The following tables show the latent debris amount calculated for the AP1000 based on debris walkdown data from several operating plants. The walkdowns provided debris data for various types of surfaces in containment. This data includes a 25% conservatism to address uncertainties related to the potential debris sources. For this evaluation, the average of debris data for similar surfaces in all the walked-down plants was used. This average was applied to the surface areas in the AP1000 containment that could be transported to the Containment Recirculation Screens or to the IRWST Screens.

As the tables show, approximately 24 lb_m of latent debris would be expected to be transported to the AP1000 Containment Recirculation Screens through direct impingement, immersion or from being washed down during a high energy line break. Similarly, approximately 5 lb_m of latent debris would be expected to migrate to the AP1000 IRWST Screens through direct impingement, immersion or from being washed down during a high energy line break. As the tables show, the percentages based on the estimated volumes convert to approximately 85% particulates, approximately 14% coatings, and less than 1% fiber based on mass.

Table 2: Containment Recirculation Screens

Debris Type	Density (lb_m/ft^3)	% Volume	Volume of Debris (ft^3)	% Mass	Mass of Debris (lb_m)
Latent Particulate	100.00	85.00	0.21	85.85	20.52
Coatings (epoxy)	94.00	2.50	0.01	2.37	0.57
Coatings (IOZ)	457.00	2.50	0.01	11.54	2.76
Latent Fiber	2.40	10.00	0.02	0.24	0.06
Totals		100.00	0.24	100.00	23.91

Table 3: IRWST Screens

Debris Type	Density (lb_m/ft^3)	% Volume	Volume of Debris (ft^3)	% Mass	Mass of Debris (lb_m)
Latent Particulate	100.00	85.00	0.05	85.85	4.67
Coatings (epoxy)	94.00	2.50	0.00	2.37	0.13
Coatings (IOZ)	457.00	2.50	0.00	11.54	0.63
Latent Fiber	2.40	10.00	0.01	0.24	0.01
Totals		100.00	0.05	100.00	5.44

The screen loadings in Tables 2 and 3 are based on the best estimate of debris amounts for AP1000. A second calculation was performed to determine an upper bound for potential screen loadings on AP1000. For this calculation, the debris loading used for each surface was the highest value of debris loading found in any similar surface in the operating plant walkdown data. In other words, this calculation is based on every AP1000 surface having the highest debris loading found in any of the plants for that type of surface. The makeup of the debris is the same but the amounts increase significantly as shown in Table 4. The upper bound amounts are referred to as the Bounding Case in Table 4.

Table 4: Debris Loadings Used in Head Loss Evaluation for Recirculation Screens, IRWST Screens and Bottom of Fuel

Screen Type	Total Latent Containment Debris Applied to Screen (lb_M)	
	Best Estimate, Based on Average Walkdown Values	Bounding Case, Based on Maximum Walkdown Values
Recirculation Screens	23.91	82.0
IRWST Screens	5.44	17.0
Core	14.35	49.2

Note that the debris reaching the core is based on a DVI LOCA in the loop compartment. For this event the containment water level rises above the break so that some water can enter the reactor coolant system (RCS) directly and thereby bypass the Containment Recirculation Screens. It is calculated for such an event that no more than 60% of the total recirculation flow will bypass the screens. As a result, the core debris is set at 60% of the Containment Recirculation Screen amount.

The debris for all screens will have the same makeup as discussed previously: approximately 85% particulates, 5% coatings, and less than 10% fiber by volume or approximately 85% particulates, 14% coatings and 1% fiber by mass. Note that rounding upward to 1% fiber by mass adds additional conservatism in the assumed amount of fiber.

It is expected that AP1000 would have debris amounts close to the Best Estimate amounts but potentially slightly higher because averages were used for each area. The Bounding Case amounts, however, are expected to conservatively bound the expected AP1000 amounts.

The use of operating plant walkdown data has allowed the AP1000 latent containment debris to be estimated considering both the expected amounts and the upper bounds. Good housekeeping practices will be incorporated into the AP1000 cleanliness program and confirmed by the revision to COL Information Item 6.3-1 as discussed in the Introduction section of this report.

Post-Accident Chemical Effects

A consideration in evaluating the effects of the debris transported to the sump after a LOCA is the chemical products which may form in the post-LOCA sump environment. Materials present in containment may dissolve or corrode when exposed to the reactor coolant. This reaction would result in oxide particulate corrosion products and the potential for the formation of precipitants due to changes in temperature and reactions with other dissolved materials. These chemical products could become another source of debris loading and impact sump screen performance and recirculation flow.

An analysis was performed to determine the type and quantity of chemical precipitants which may form in the post-LOCA recirculation fluid for the AP1000 design. The analysis evaluated these post-LOCA chemical effects using the methodology developed in WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191" (Reference 4). This methodology has been used for sump screen performance testing for existing plants, and may be used by AP1000.

Table 5 lists the predicted precipitants for the AP1000 chemical model evaluation using conservative containment material amounts. The results have been calculated using the minimum post-accident recirculation volume of coolant for the AP1000. Table 5 also lists the chemical precipitants in terms of a mass concentration using the minimum recirculation water volume.

Table 5: AP1000 Predicted Chemical Precipitate Formation

Precipitants	kg	lb	ppm
$NaAlSi_3O_8$	1.5	3.3	0.6
AlOOH	19.7	43.4	8.3
$Ca_3(PO_4)_2$	0.5	1.1	0.2

Note that the AP1000 has several features that significantly reduce the amounts of materials that could contribute to the formation of chemical precipitants. The AP1000 containment has little concrete that can come in contact with the post accident water as a result of the use of structural steel module construction. The only identified aluminum in the AP1000 containment is in the excore detectors. These detectors are enclosed in stainless steel so that post accident containment water will not circulate against the aluminum. A limited amount of aluminum has been arbitrarily included in the above calculations for conservatism.

A sensitivity evaluation was also performed to determine the additional precipitant generation that might occur from zinc materials in containment being exposed to the sump liquid. This sensitivity determined that less than 1 kg of zinc is released into solution when the limiting case with contingency was considered. This amount is relatively small and is determined to be negligible to the overall precipitant generation.

This evaluation shows that the potential amount of chemical precipitants available in the AP1000 containment is significantly lower than in current plants.

<u>Head Loss Calculations</u>

The effect of latent containment debris on the performance of equipment used in post-LOCA recirculation is a part of the GSI-191 issue for the PWR Industry. In recent years, much data has been collected and programs have been developed to determine the amount and effects of latent debris on post-LOCA equipment and to mitigate the negative effects of that latent debris. One effect of latent debris in post-LOCA recirculation mode is the head loss due to debris building up on screens. A large loss of head across Containment Recirculation Screens could restrict the AP1000 recirculation flow required to cool the core effectively.

The pressure drop across the AP1000 Containment Recirculation Screens due to latent debris building up on the screen under natural circulation conditions was calculated. Calculations were also made for pressure drop across the AP1000 IRWST Screens resulting from latent containment debris accumulation on the screen under accident conditions. Finally, calculations were made for pressure drops at the AP1000 core resulting from debris accumulation on the bottom of the fuel. The reason for considering debris accumulation on the fuel is that for a DVI line break there is a potential for some flow from the sump to bypass the Containment Recirculation Screens by flowing into the reactor vessel downcomer directly through the break location. To evaluate the resulting head loss, the bottom nozzles of the fuel were treated as a screen.

Two latent containment debris loading cases were evaluated:

1. The Bounding Case in Table 4 which uses maximum surface debris loadings from walkdowns in existing plants. This case assumes a fiber content of 1% by mass based on operating plant measurements.

2. A "Sensitivity" Case which assumes a total of 200 lb_M of latent containment debris migrates to the screens. The total amount of debris in the containment would be somewhat higher since the latent debris in some containment areas would not migrate to either set of screens. The 200 lb_M was chosen because it is the NRC-recommended value for latent containment debris in their Safety Evaluation to NEI 04-07 (Reference 5). This sensitivity case assumes a fiber content of 1% by mass based on operating plant measurements. This case is provided to demonstrate that the AP1000 base case is not close to a "cliff" where there might be significantly reduced margins.

The amount of debris applied to the screen surfaces was apportioned based on flow to these surfaces.

Table 6 provides the debris loadings used for the Sensitivity Case as compared with the Table 4 debris loadings.

Table 6: Debris Loadings Used in Head Loss Evaluation for Recirculation Screens, IRWST Screens and Bottom of Fuel

Screen Type	Total Latent Containment Debris Applied to Screen (lb_M)		
	Best Estimate, Based on Average Walkdown Values	Bounding Case, Based on Maximum Walkdown Values	Sensitivity Case
Recirculation Screens	23.91	82.0	165.0
IRWST Screens	5.44	17.0	35.0
Core	14.35	49.2	99.0

Table 7 summarizes the results of calculations performed for the AP1000 using the above debris loadings. Note that a calculated uncompacted fiber bed thickness of 0.125 inches is generally accepted as being required to form a debris bed.

Table 7: Summary of Head Losses for AP1000 PXS Containment Recirculation Screens, IRWST Screens and Core

Screen	Case	Screen Debris (lb)	% Fiber by Mass	Head Loss (ft_{H2O})	Calculated Uncompacted Bed Thickness (in.)
Containment Recirculation Screen	Bounding	82	1%	0.00	0.0008
	Sensitivity	165	1%	0.00	0.025
IRWST Screen	Bounding	17	1%	0.00	0.0017
	Sensitivity	35	1%	0.00	0.0122
Core	Bounding	49.2	1%	0.00	0.0387
	Sensitivity	99	1%	0.00	0.0780

From Table 7 the following conclusions are drawn:

For the Containment Recirculation Screens and the IRWST Screens:

- Because the calculated uncompacted bed thickness is less than 0.125 inches, there is insufficient fiber to form a continuous fiber bed on either screen.
- Since a continuous fiber bed cannot be formed, there would be "clean screen" area available.
- The availability of clean screen area and the small amount of post-accident chemical products predicted for the AP1000 design indicate that post-accident chemical precipitants will not challenge the flow through either the Containment Recirculation screen or the IRWST Screen.
- The resulting head loss across these screens is negligible.

For the Core:

- There is insufficient fiber to form a continuous fiber bed on the bottom of the fuel.

- Since a continuous fiber bed cannot be formed, there would be "clean screen" area available on the bottom of the fuel.
- The availability of clean screen area and the small amount of post-accident chemical products predicted for the AP1000 design indicate that post-accident chemical precipitants will not challenge the flow through the fuel.
- The resulting head loss at the bottom of the fuel is negligible.

Therefore, the existence of latent debris in containment and the formation of chemical products due to the post-accident reaction of materials that contact coolant collected on the containment floor are evaluated to not have an adverse impact on the performance of the PXS.

<u>References</u>

1. Nuclear Regulatory Commission Regulatory Guide 1.82, Rev.3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident, November 2003
2. Nuclear Regulatory Commission Generic Letter GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," September 2004
3. NEI 02-01, Rev. 1, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," September 2002
4. WCAP-16530-NP, Revision 0, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," February 7, 2006
5. NEI 04-07, Revision 0 "Pressurized Water Reactor Sump Performance Evaluation Methodology", December 2004

REGULATORY IMPACT

<u>Design Function</u>

The changes to the DCD presented in this report do not represent an adverse change to the design function or to how design functions are performed or controlled. The changes to the DCD do not involve revising or replacing a DCD-described evaluation methodology nor involve a test or experiment not described in the DCD. The DCD change does not require a license amendment per the criteria of VIII.B.5.b. of Appendix D to 10CFR Part 52.

<u>Severe Accident Change Criteria</u>

The DCD changes do not result in a negative impact on features that mitigate severe accidents. There is therefore no increase in the probability or consequences of a severe accident.

<u>Security</u>

The closure of the COL Information Items will not alter barriers or alarms that control access to protected areas of the plant. The closure of the COL Information Items will not alter requirements for security personnel. Therefore, the closure of the COL Information Item does not have an adverse impact on the security assessment of the AP1000.

DCD MARK-UP

Attachment A provides the DCD markup showing how COL applications should be prepared to incorporate the subject information. Note that page breaks vary slightly from the DCD.

AP1000 Standard Combined License Technical Report

AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA

Attachment A
DCD Markup

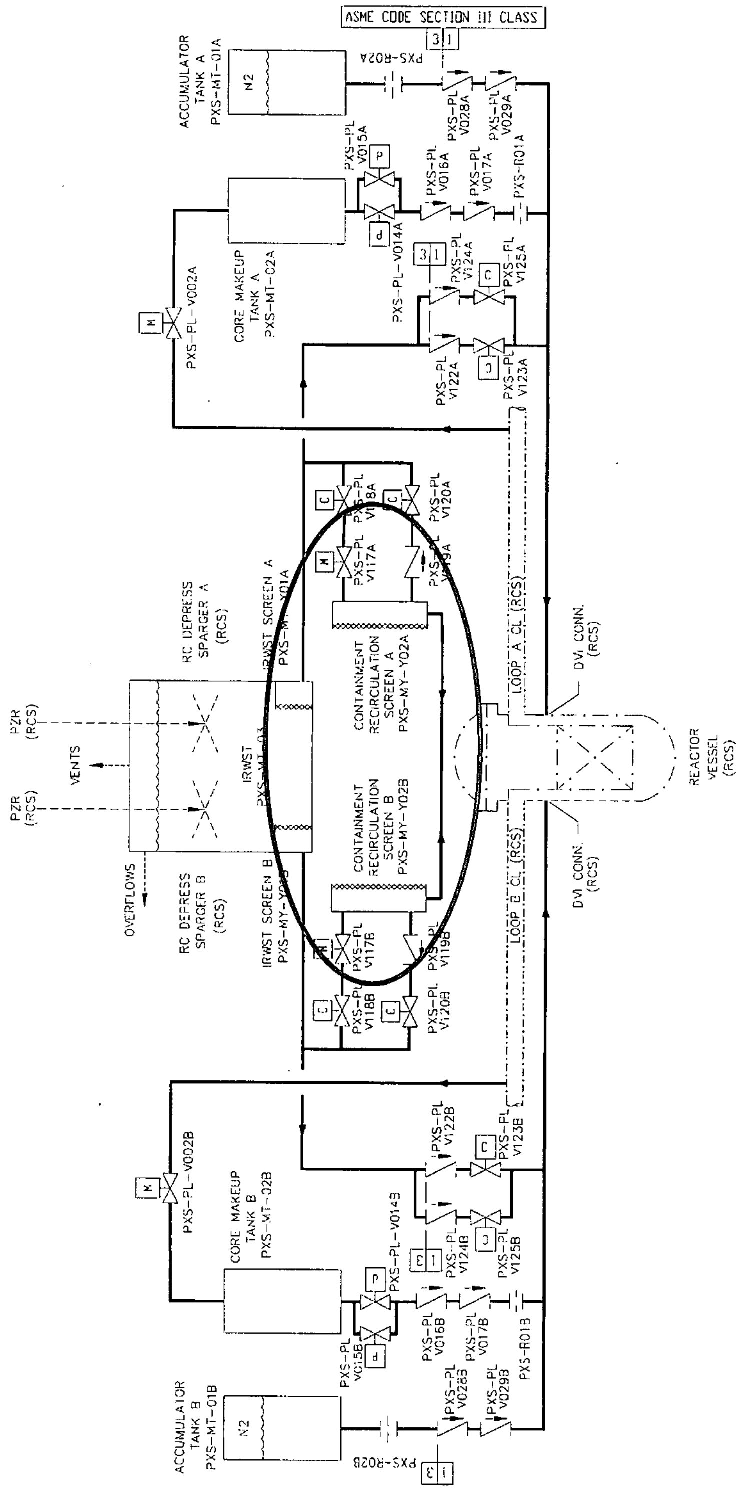
The following revised DCD sections are included:

Tier 1:
- ITAACS Table 2.2.3-4
- Figure 2.2.3-1 (Sheet 2 of 2)

Tier 2:
- Section 6.3.2.2.7.1
- Section 6.3.2.2.7.2
- Section 6.3.2.2.7.3
- Section 6.3.8.1
- Section 6.3.8.2
- Section 6.3.9
- Table 6.3-2 (Sheet 2 of 2)
- Figure 1.2-6
- Figure 1.2-9
- Figure 3E-4
- Figure 6.3-2
- Figure 6.3-3
- Figure 6.3-6
- Figure 6.3-7
- Figure 6.3-8
- Figure 6.3-9
- Figure 9A-1 (Sheet 4 of 16)
- Figure 12.3-1 (Sheet 5 of 16)
- Figure 12.3-2 (Sheet 5 of 16)
- Figure 12.3-3 (Sheet 5 of 16)

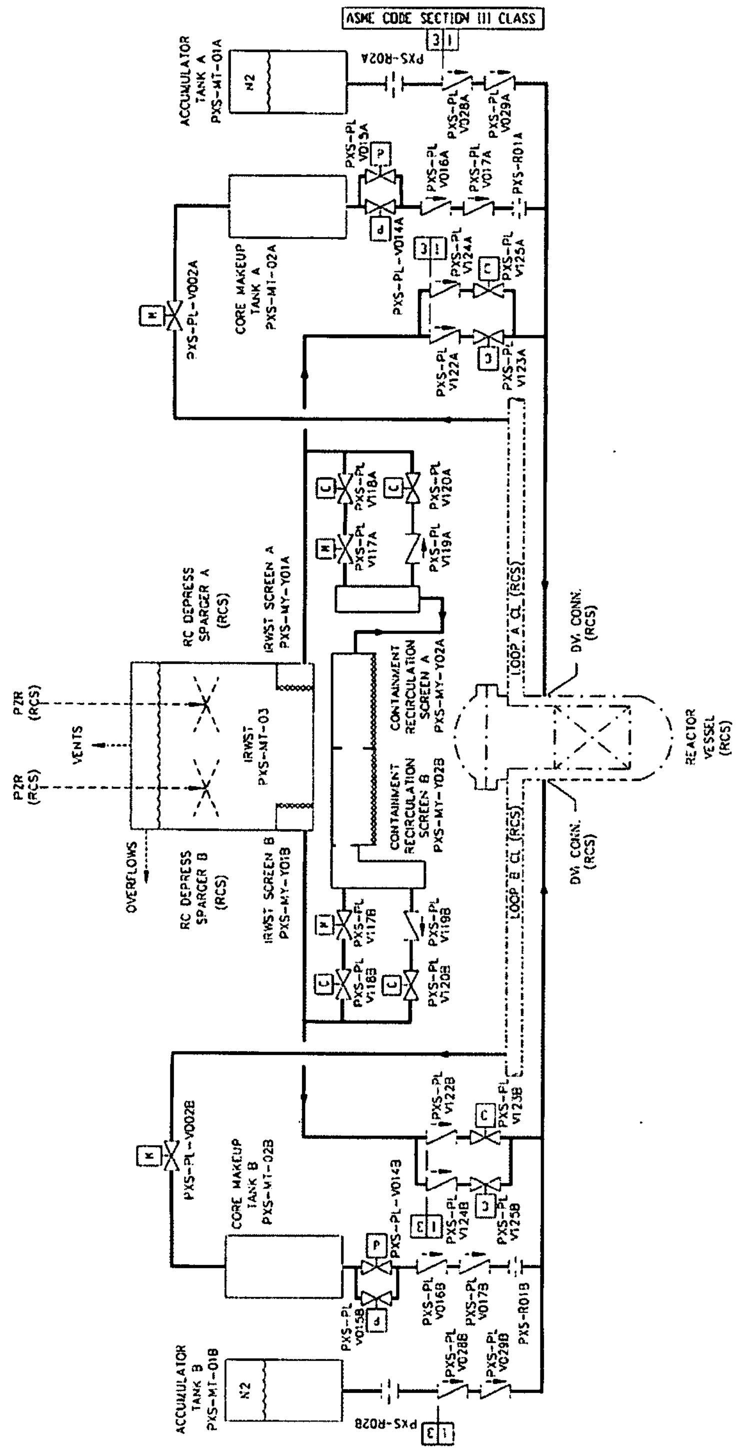
Table 2.2.3-4 (cont.)
Inspections, Tests, Analyses, and Acceptance Criteria

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
	vii) Inspection of the as-built components will be conducted for plates located above the containment recirculation screens.	vii) Plates located above each containment recirculation screen are no more than 1 ft above the top of the screen and extend out at least 10 ft perpendicular to and at least 7 ft to the side of ~~the trash rack portion of~~ the screen surface.
	viii) Inspections of the IRWST and containment recirculation screens will be conducted.	viii) The screen surface ~~area (width x height) of each screen trash rack is $\geq$ 70 ft^2 and~~ of each ~~fine~~ IRWST screen is $\geq$ ~~140~~ 500 ft^2 (unfolded area). The screen surface area of each containment recirculation screen is > 2500 ft^2. The bottom of the containment recirculation screens is $\geq$ 2 ft above the loop compartment floor.
	ix) Inspections will be conducted of the insulation used inside the containment on ASME Class 1 lines and on the reactor vessel, reactor coolant pumps, pressurizer and steam generators.	ix) The type of insulation used on these lines and equipment is a metal reflective type or a suitable equivalent.
	x) Inspections will be conducted of the as-built nonsafety-related coatings or of plant records of the nonsafety-related coatings used inside containment on walls, floors, ceilings, structural steel which is part of the building structure and on the polar crane.	x) A report exists and concludes that the coatings used on these surfaces has a dry film density of $\geq$ 100 lb/ft^3.
	xi) Inspection of the as-built CMT inlet diffuser will be conducted.	xi) The CMT inlet diffuser has a flow area $\geq$ 165 in^2.
	xii) Inspections will be conducted of the CMT level sensors (PSX-11A/B/D/C, - 12A/B/C/D, - 13A/B/C/D, - 14A/B/C/D) upper level tap lines.	xii) The centerline of each upper level tap line at the tee for each level sensor is located 1" $\pm$ 1" below the centerline of the upper level tap connection to the CMT.



DCD Figure 2.2.3-1 (Sheet 2 of 2)
Passive Core Cooling System

Current DCD Figure Showing Area to be Revised



DCD Figure 2.2.3-1 (Sheet 2 of 2)
Passive Core Cooling System

Revised DCD Figure

submerged below the in-containment refueling water storage tank overflow level by ≤11.5 feet. The component data for the spargers is shown in Table 6.3-2. The spargers are AP1000 Equipment Class C and are designed to meet seismic Category I requirements.

The spargers perform a nonsafety-related function -- minimizing plant cleanup and recovery actions following automatic depressurization. They are designed to distribute steam into the in-containment refueling water storage tank, thereby promoting more effective steam condensation.

The first three stages of automatic depressurization system valves discharge through the spargers and are designed to pass sufficient depressurization venting flow, with an acceptable pressure drop, to support the depressurization system performance requirements. The installation of the spargers prevents undesirable and/or excessive dynamic loads on the in-containment refueling water storage tank and other structures.

Each sparger is sized to discharge at a flow rate that supports automatic depressurization system performance, which in turn, allows adequate passive core cooling system injection.

6.3.2.2.7 IRWST and Containment Recirculation Screens

The passive core cooling systems has two different sets of screens that are used following a LOCA; IRWST screens and containment recirculation screens. These screens prevent debris from entering the reactor and blocking core cooling passages during a LOCA. These screens are designed to comply with applicable licensing regulations including:

- GDC 35 of 10 CFR 50 Appendix A
- Regulatory Guide 1.82
- NUREG-0897

The operation of the passive core cooling system following a LOCA is described in subsection 6.3.2.1.3. Proper screen design, plant layout, and other factors prevent clogging of these screens by debris during accident operations.

6.3.2.2.7.1 General Screen Design Criteria

1. Screens are designed to Regulatory Guide 1.82, including:
   - Redundant screens are provided for each function
   - Separate locations are used for redundant screens
   - Screens are located well below containment floodup level. Each screen provides the function of ~~has~~ a trash rack~~coarse, and~~ a fine screen, and a debris curb
   - Floors slope away from screens (not required for AP1000)
   - Drains do not impinge on screens

6.3.2.2.7.2 IRWST Screens

The IRWST screens are located inside the IRWST at the bottom of the tank. Figure 6.3-6 shows a plan view and Figure 6.3-7 shows a section view of these screens. Two separate screens are provided in the IRWST, one at either end of the tank. The IRWST is closed off from the containment; its vents and overflows are normally closed by louvers. The potential for introducing debris inadvertently during plant operations is limited. A COL cleanliness program (refer to subsection 6.3.8.1) controls foreign debris from being introduced into the tank during maintenance and inspection operations. The Technical Specifications require visual inspections of the screens during every refueling outage.

The IRWST design eliminates sources of debris from inside the tank. Insulation is not used in the tank. Air filters are not used in the IRWST vents or overflows. Wetted surfaces in the IRWST are corrosion resistant such as stainless steel or nickel alloys; the use of these materials prevents the formation of significant amounts of corrosion products. In addition, the water is required to be clean because it is used to fill the refueling cavity for refueling; filtering and demineralizing by the spent fuel pit cooling system is provided during and after refueling.

During a LOCA, steam vented from the reactor coolant system condenses on the containment shell, drains down the shell to the operating deck elevation and is collected in a gutter. It is very unlikely that debris generated by a LOCA can reach the gutter because of its location. The gutter is covered with a trash rack which prevents larger debris from clogging the gutter or entering the IRWST through the two 4 inch drain pipes. The inorganic zinc coating applied to the inside surface of the containment shell is one potential source of debris that may enter the gutter and the IRWST. As described in subsection 6.1.2.1.5, failure of this coating produces a heavy powder which if it enters the IRWST through the gutter will settle out on the bottom of the IRWST because of its high specific gravity. Settling is enhanced in the IRWST by low velocities in the tank and long tank drain down times.

The design of the IRWST screens reduces the chance of debris reaching the screens. The screens are oriented vertically such that debris that settles out of the water does not fall on the screens. The screen design provides aA debris curb functionlocated at the base of the IRWST screens to prevents high density debris from being swept along the floor by water flow to the IRWST screens. The screen design provides the trash rack function. This is accomplished by the screens having a large surface area to prevent a single object from blocking a large portion of the screen and by the screens having a robust design to preclude an object from damaging the screen and causing by-pass. The IRWST screens are made up of a trash rack and a fine screen. The trash rack prevents larger debris from reaching the finer screen. The fine screen prevents debris larger than 0.125" from being injected into the reactor coolant system and blocking fuel cooling passages. The fine screen is a folded type (folded, pockets, etc.) that has sufficientmore surface area ~~than the trash rack~~ to accommodate debris that could ~~pass through the trash rack and~~ be trapped on the ~~fine~~ screen.

The screen flow area is conservatively designed considering the operation of the nonsafety-related normal residual heat removal system pumps which produce a higher flow than the safety-related gravity driven IRWST injection/recirculation flows. As a result, when the normal residual heat removal system pumps are not operating there is a large margin to screen clogging.

6.3.2.2.7.3 Containment Recirculation Screens

The containment recirculation screens are oriented vertically along walls above the loop compartment floor (elevation 83 feet). Figure 6.3-8 shows a plan view and Figure 6.3-9 shows a section view of these screens. Two separate screens are provided as shown in Figure 6.3-3. The loop compartment floor elevation is significantly above (11.5 feet) the lowest level in the containment, the reactor vessel cavity. The bottom of the recirculation screen is two ~~foot~~ feet above the floor, providing a curb function.

During a LOCA, the reactor coolant system blowdown will tend to carry debris created by the accident (pipe whip/jets) into the cavity under the reactor vessel which is located away from and below the containment recirculation screens. As the accumulators, core makeup tanks and IRWST inject, the containment water level will slowly rise above the 108 foot elevation. The containment recirculation line opens when the water level in the IRWST drops to a low level setpoint a few feet above the final containment floodup level. When the recirculation lines initially open, the water level in the IRWST is higher than the containment water level and water flows from the IRWST backwards through the containment recirculation screen. This back flow tends to flush debris located close to the recirculation screens away from the screens. A cross connect pipe line interconnects the two PXS subsystems ~~recirculation screens~~ so that both recirculation screens will operate, even in the case of a LOCA of a DVI line in a PXS valve room. Such a LOCA can flood the recirculation valves located in one of the PXS rooms before they are actuated, and the failure of these valves is assumed since they are not qualified to operate in such conditions. The recirculation valves in the other PXS valve room are unaffected.

The water level in the containment when recirculation begins is well above (~ 10 feet) the top of the recirculation screens. During the long containment floodup time, floating debris does not move toward the screens and heavy materials settle to the floors of the loop compartments or the reactor vessel cavity. During recirculation operation the containment water level will not change significantly nor will it drop below the top of the screens.

The amount of debris that may exist following an accident is limited. Reflective insulation is used to preclude fibrous debris that can be generated by a loss of coolant accident and be postulated to reach the screens during recirculation. The nonsafety-related coatings used in the containment are designed to withstand the post accident environment. The containment recirculation screens are protected by plates located above them. These plates prevent debris from the failure of nonsafety-related coatings from getting into the water close to the screens such that the recirculation flow can cause the debris to be swept to the screens before it settles to the floor. Stainless steel is used on the underside of these plates and on surfaces located below the plates, above the bottom of the screens, 10 feet in front and 7 feet to the side of the screens to prevent coating debris from reaching the screens.

A COL cleanliness program (refer to subsection 6.3.8.1) controls foreign debris introduced into the containment during maintenance and inspection operations. The Technical Specifications require visual inspections of the screens during every refueling outage.

The design of the containment recirculation screens reduces the chance of debris reaching the screens. The screens are orientated vertically such that debris settling out of the water will not fall on the screens. The protective plates described above provide additional protection to the screens from debris. The bottom of the screens are located 2 feet above the floor, instead of using a debris curb, to prevent high density debris from being swept along the floor by water flow to the containment recirculation screens. The screen design provides the trash rack function. This is accomplished by the screens having a large surface area to prevent a single object from blocking a large portion of the screen and by the screens having a robust design to preclude an object from damaging the screen and causing by-pass. ~~The containment recirculation screens are made up of a trash rack and a fine screen. The trash rack prevents larger debris from reaching the finer screen.~~ The ~~fine~~ screen prevents debris larger than 0.125" from being injected into the reactor coolant system and blocking fuel cooling passages. ~~The fine screen prevents debris larger than 0.125" from being injected into the reactor coolant system and blocking fuel cooling passages.~~ The ~~fine~~ screen is a ~~folded~~ type (folded, pocket, etc.) that has more surface area ~~than the trash rack~~ to accommodate debris that could ~~pass through the trash rack and~~ be trapped on the fine screen.

The screen flow area is conservatively designed, considering the operation of the normal residual heat removal system pumps, which produce a higher flow than the gravity driven IRWST injection/recirculation flows. As a result, when the normal residual heat removal system pumps are not operating there is even more margin in screen clogging.

6.3.8.1 Containment Cleanliness Program

The Combined License applicants referencing the AP1000 will address preparation of a program to limit the amount of debris that might be left in the containment following refueling and maintenance outages. The cleanliness program will limit the storage of outage materials (such as temporary scaffolding and tools) inside containment during power operation consistent with COL item 6.3.8.2. The cleanliness program will be consistent with the containment cleanliness program used in the evaluation discussed in Section 6.3.8.2

6.3.8.2 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA

The Combined License information requested in this subsection has been addressed in APP-GW-GLR-079 (Reference 3) and the applicable changes are incorporated into the DCD. No additional work is required by the Combined Operating License Applicant to address the aspects of the Combined License information requested in this subsection as delineated in the following paragraph:

The completed evaluation documented in APP-GW-GLR-079 (Reference 3) is consistent with Regulatory Guide 1.82 Revision 3 and demonstrates that adequate long-term core cooling is available considering debris resulting from a LOCA and debris that might exist in containment prior to a LOCA.

The following words represent the original Combined Operating License Information Item commitment, which has been addressed as discussed above.

The Combined License applicants referencing the AP1000 will perform an evaluation consistent with Regulatory Guide 1.82, revision 3, to demonstrate that adequate long-term core cooling is available considering debris resulting from a LOCA together with debris that exists before a LOCA. As discussed in DCD subsection 6.3.2.2.7.1, a LOCA in the AP1000 does not generate fibrous debris due to damage to insulation or other materials included in the AP1000 design. The evaluation will consider resident fibers and particles that could be present considering the plant design, location, and containment cleanliness program. The determination of the characteristics of such resident debris will be based on sample measurements from operating plants. The evaluation will also consider the potential for the generation of chemical debris (precipitants). The potential to generate such debris will be determined considering the materials used inside the AP1000 containment, the post-accident water chemistry of the AP1000, and the applicable research/testing.

6.3.9 References

1. WCAP-8966, "Evaluation of Mispositioned ECCS Valves," September 1977.
2. WCAP-13594 (P), WCAP-13662 (NP), "FMEA of Advanced Passive Plant Protection System," Revision 1, June 1998.
3. APP-GW-GLR-079, AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA, Revision 0, April 2007

Table 6.3-2 (Sheet 2 of 2)

COMPONENT DATA - PASSIVE CORE COOLING SYSTEM

IRWST		
Number	1	
Type	Integral to containment internal structure	
Volume, minimum water (cubic feet)	73,900	
Design pressure (psig)	5	
Design temperature (°F)	150 *	
Material	Wetted surfaces are stainless steel	
AP1000 equipment class	C	
Spargers		
Number	2	
Type	Cruciform	
Flow area of holes (in^2)	274	
Design pressure (psig)	600	
Design temperature (°F)	500	
Material	Stainless Steel	
AP1000 equipment class	C	
pH Adjustment Baskets		
Number	4	
Type	Rectangular	
Volume minimum total (cubic feet)	560	
Material	Stainless steel	
AP1000 equipment class	C	
Screens	IRWST	Containment Recirculation
Number	2	2 (Connected)
~~Surface area, trash rack (square feet)~~	~~≥70~~	~~≥70~~
Surface area, ~~fine~~ screen (square feet)	~~≥140~~ 500 per screen	~~≥140~~ 2500 per screen
Material	Stainless steel	Stainless steel
AP1000 equipment class	C	C

Note:
* Several times during plant life, the refueling water could reach 250°F.

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 1.2-6

Nuclear Island General Arrangement
Plan at Elevation 96′-6″

Current DCD Figure Showing Area to be Revised

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 1.2-6

Nuclear Island General Arrangement

Plan at Elevation 96′-6″

Revised DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 1.2-9

Nuclear Island General Arrangement
Plan at Elevation 117′-6″ with Equipment

Current DCD Figure Showing Area to be Revised

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 1.2-9

Nuclear Island General Arrangement
Plan at Elevation 117′-6″ with Equipment

Revised DCD Figure

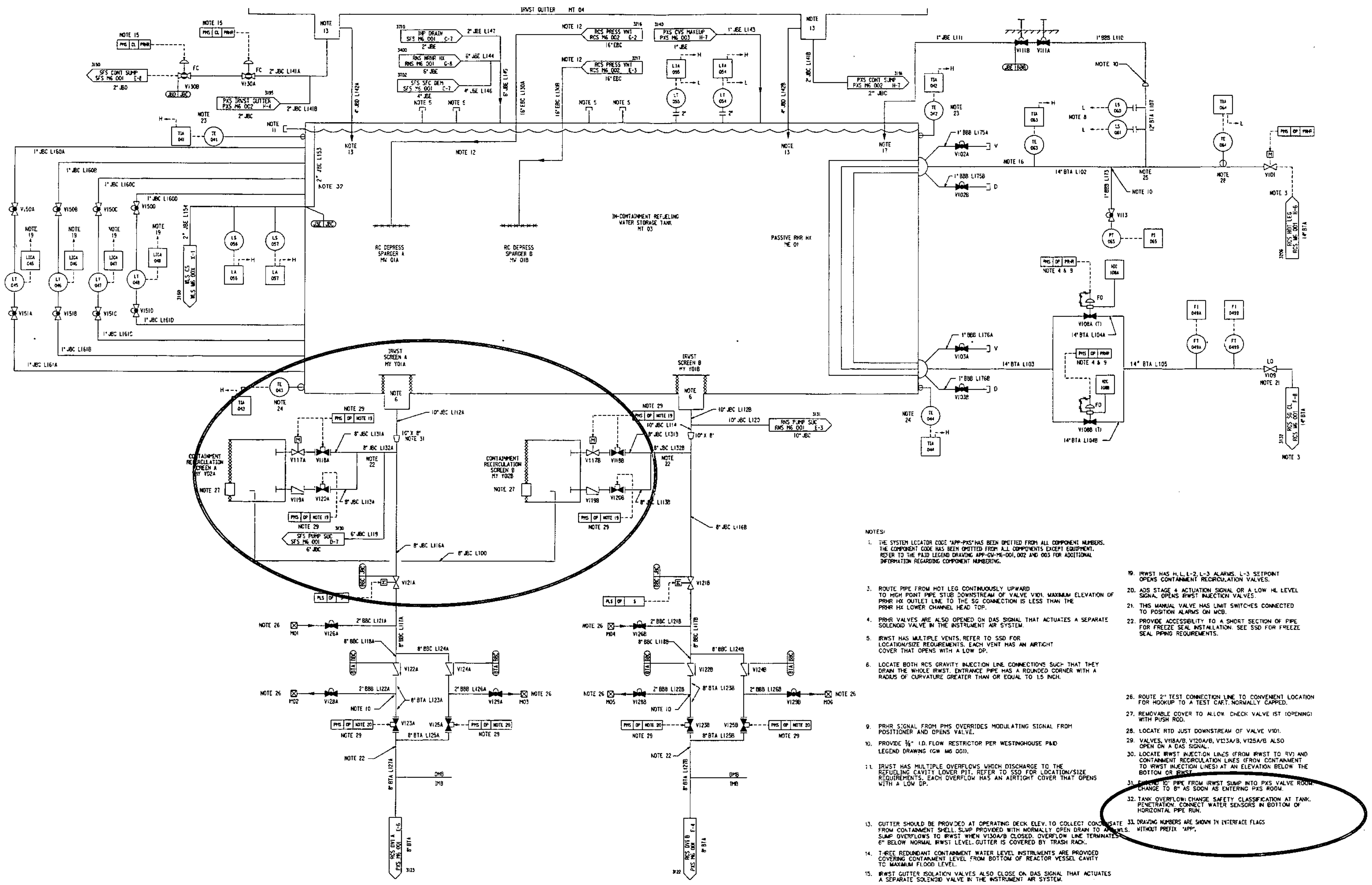


Figure 6.3-2

Passive Core Cooling System
Piping and Instrumentation Diagram (Sheet 2)

Current DCD Figure Showing Areas to be Revised

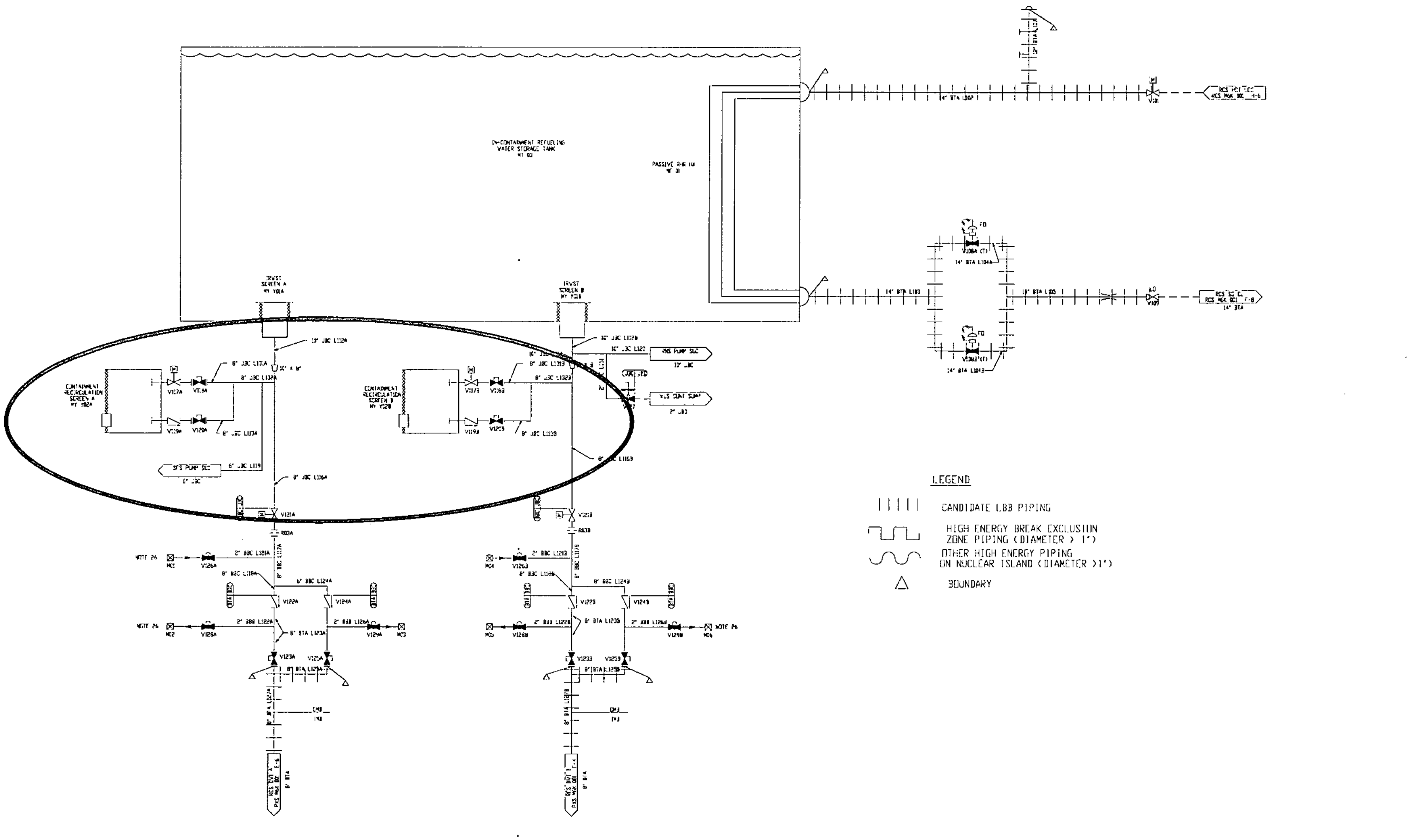


Figure 3E-4 (Sheet 2 of 2)
High Energy Piping – Passive Core Cooling System

Modifications in indicated area same as modifications to Figure 6.3-2

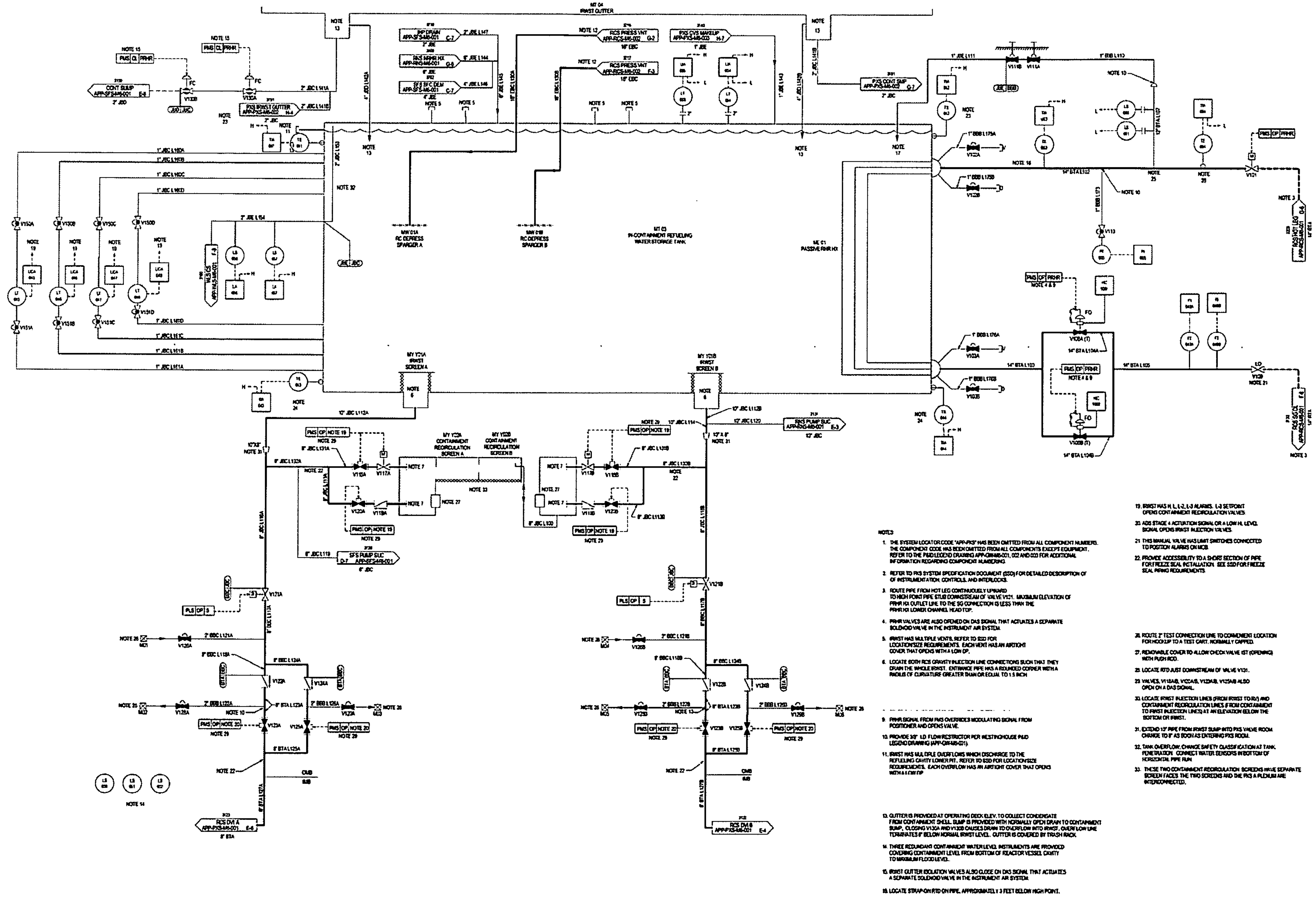


Figure 6.3-2
Passive Core Cooling System
Piping and Instrumentation Diagram (Sheet 2)

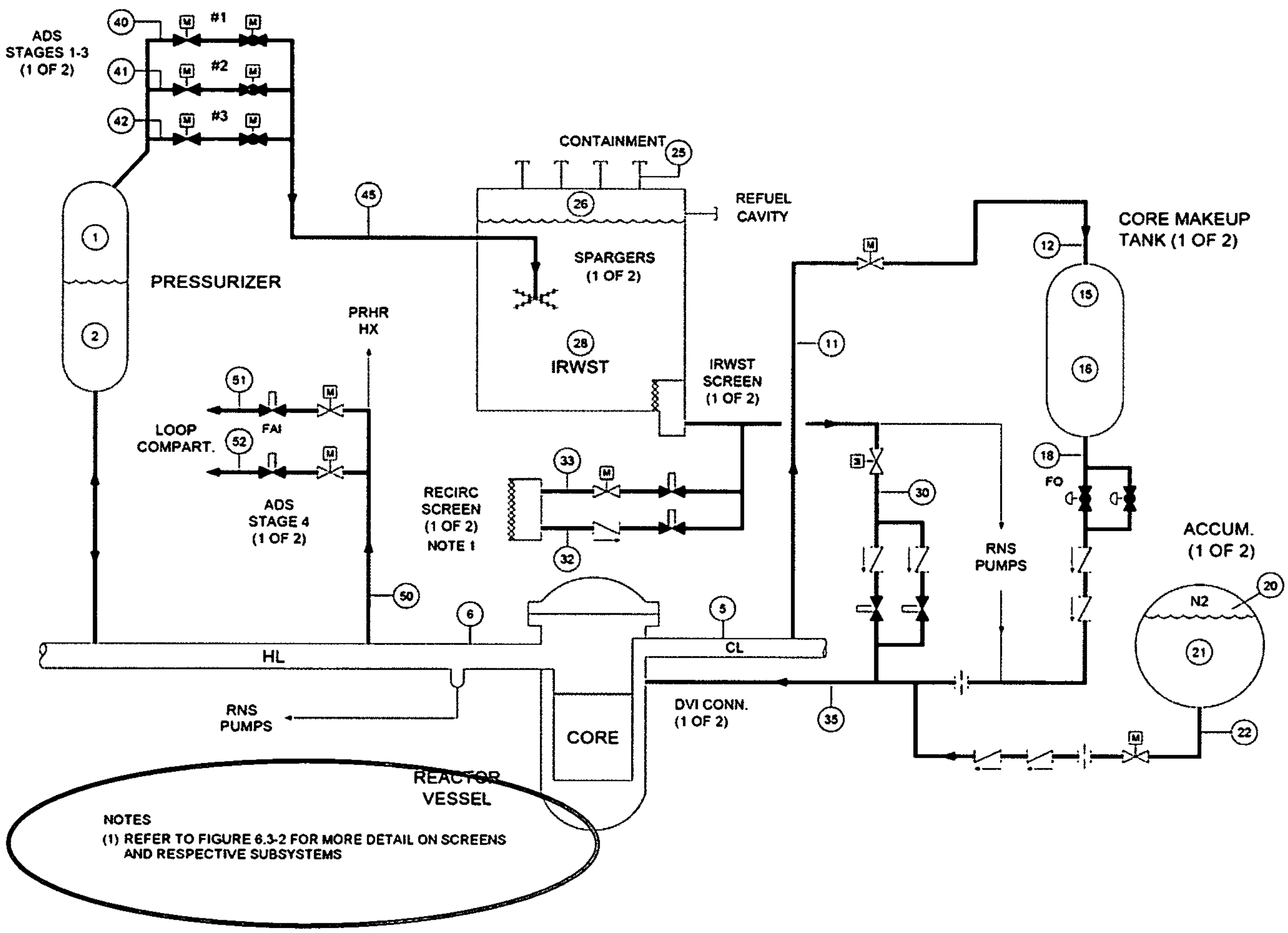
Revised DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 9A-1 (Sheet 4 of 16)

[Nuclear Island Fire Area Plan at Elevation 96'-6"]*

Current DCD Figure Showing Area to be Revised



Inside Reactor Containment
Figure 6.3-3

Passive Safety Injection
(REF) RCS & PXS

Revised DCD Figure with addition circled.

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 6.3-6

IRWST Screen Plan Location

Current DCD Figure Showing Area to be Revised

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 6.3-6

IRWST Screen Plan Location

Revised DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 6.3-7

IRWST Screen Section Location

Current DCD Figure Showing Area to be Revised

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 6.3-7

IRWST Screen Section Location

Revised DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 6.3-8
Containment Recirculation Screen Location Plan

Current DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 6.3-8
Containment Recirculation Screen Location Plan

Revised DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 6.3-9

Containment Recirculation Screen Location Elevation

Current DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 6.3-9

Containment Recirculation Screen Location Elevation

Revised DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 9A-1 (Sheet 4 of 16)

[Nuclear Island Fire Area Plan at Elevation 96'-6"]*

Revised DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Current DCD Figure Showing Area to be Revised

Figure 12.3-1 (Sheet 5 of 16)

**Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 96′-6″**

Security-Related Information, Withhold Under 10 CFR 2.390d

Revised DCD Figure

Figure 12.3-1 (Sheet 5 of 16)

**Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 96′-6″**

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 12.3-2 (Sheet 5 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 96′-6″

Current DCD Figure Showing Area to be Revised

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 12.3-2 (Sheet 5 of 15)

**Radiation Zones, Post-Accident
Nuclear Island, Elevation 96′-6″**

Revised DCD Figure

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 12.3-3 (Sheet 5 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 96′-6″

Current DCD Figure Showing Area to be Revised

Security-Related Information, Withhold Under 10 CFR 2.390d

Figure 12.3-3 (Sheet 5 of 16)

**Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 96′-6″**

Revised DCD Figure