ENCLOSURE 2

APP-GW-GLR-079-NS, Revision 2

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

Technical Report Number 26
(Redacted Version)

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****Plant Applicability**: ☒ All AP1000 plants except:
☐ Only the following plants:

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AP1000 Standard Combined License Technical Report

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

Revision 2

Public (redacted) Version with sensitive unclassified non-safeguards information (SUNSI) related to the physical protection of an AP1000 Nuclear Plant withheld under 10 CFR 2.390.

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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.

Revision 2 of this technical report is submitted to address NRC concerns related to long term core cooling.

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 design control document (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	280	5000

Recirculation		
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.

Damage to the screens that would allow by-pass is not acceptable for PWR designs. The perforated steel plate design of the AP1000 recirculation screens provides for sufficient strength of the screens to protect against damage from impact loading that would result in debris bypass through damage sites. Therefore, the location of trash racks in front of the screens to protect against damage to the screens from impact loading is unnecessary..

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 large increase in screen area allows for better management of debris that can reach the screen. To create a "thin-bed effect" the fibrous debris (of which there is only resident debris in AP1000) must mat on the screen, and the addition of >4000ft^2 of screen area does not allow the debris to form a contiguous fiber bed. The two Containment Recirculation Screens are located next to each other and are interconnected by an opening at their interfacing ends. The redundancy in screen is maintained by the size of the new screens; note that blockage by large material (tarp, large plastic sheet, etc.) is precluded by the size of the screens and the containment cleanliness program and not by separation of the screens. The two separate screens communicate with each other through an opening at their adjoining ends. The opposite ends of the screens are connected to plenums, one directly and one through a cross-over pipe. By connecting the plenums through the screens and cross-over pipe either set of recirculation piping can use the full area of the containment recirculation screen, and thus the redundancy of long term core cooling capability is maintained. The cross-over pipe was approved by the NRC in the AP1000 FSER (Reference 9). 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. Each plenum has two suction lines which are connected to ~~redundant~~ Passive Core Cooling System (PXS) direct vessel injection (DVI) lines. Each of the two DVI lines and their respective water sources can provide 100% core cooling capacity in a design basis event. The long term core cooling recirculation water flows through the following downstream components:

Table 2: Containment Recirculation Flow Path

	Description	Size and Schedule (Piping) / Number (Valves)	Minimum Diameter (inches)	Note
1	Recirculation Screens	-	0.125"	
2	Cross-Over Pipe	8" Sch 40S	7.981	1
3	Recirculation Pipe	8" Sch 40S	7.981	2

4	Gate Valve	8" / 1 (2)	≥ 5.1	3
5	Check Valve	8" / 2 (1)	≥ 5.1	3
6	Squib Valve	8" / 2	≥ 5.1	4
7	DVI Pipe	8" Sch 160	6.813	2
8	Venturi	1	4	5

Notes

1. Only one recirculation subsystem will have flow through the cross-over pipe.
2. The piping changes from schedule 40S to 160 downstream of the IRWST injection squib valves.
3. The piping has two paths for each recirculation subsystem, each path travels through the following valves check or gate, squib, gate, check, and squib. The value in parentheses show where the number of valves differ.
4. A squib valve, when open, has similar characteristics to a standard straight through gate valve.
5. This venturi represents the smallest passage in the recirculation piping. The venturi is used to choke reverse flow during an RCS blowdown.

Once the water flows through the venturi it is directed into the downcomer. It is important to note that the flow does not pass through any pumps, because AP1000's passive design does not utilize pumped recirculation flow.

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. The IRWST injection water runs through the following downstream components:

Table 3: IRWST Injection Flow Path

	Description	Size and Schedule (Piping) / Number (Valves)	Minimum Diameter (inches)	Note
1	IRWST Screen	-	0.125"	
2	IRWST Injection Pipe	10" Sch 40S	10.020	1
3	Reducer	10" x 8"	7.981	1
4	IRWST Injection Pipe	8" Sch 40	7.981	2
5	Gate Valve	8" / 1	≥ 5.1	
6	Check Valve	8" / 1	≥ 5.1	
7	Squib Valve	8" / 1	≥ 5.1	3
8	DVI Pipe	8" Sch 160	6.813	2
9	Venturi	1	4	4

Notes

1. IRWST injection pipe begins as 10" schedule 40S and reduces into 8" schedule 40 pipe.
2. The piping changes from Sch 40S to 160 downstream of the squib valves.
3. A squib valve, when open, has similar internal flow paths to a standard gate valve.
4. This venturi represents the smallest passage in the recirculation piping. The venturi is used to choke reverse flow during an RCS blowdown.

When the IRWST is heated up and boiled by operation of the PRHR, or when steam is generated in containment following a LOCA, the steam will condense on the containment shell will and drain down to the IRWST return gutters. The gutters return this water to the IRWST. For the postulated LOCA, this collection process provides for some recirculation flow from the IRWST to the core during the event.

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 to the core by the PXS 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.
- The water velocities approaching the recirculation screens have been reduced by the increase in face area of the recirculation screens; the recirculation screen face areas have been increased by approximately 55% which reduces the approach velocity by a similar amount.
- Metal reflective insulation (MRI), which contains no fibrous material , 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 drops of condensation falling from the containment dome during passive containment system (PCS) operation. It is important to note that during PCS operation the majority of condensation is returned to the IRWST via filming on the walls that the AP1000 does not have a containment spray system that would be used during a design basis accident and that during PCS operation the majority of condensation is returned to the IRWST via the IRWST gutter. 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.

Break Selection Criteria

The industry has provided guidance in Reference 6 for the selection of break location within a pressurized water reactor (PWR) and its effect on debris generation and composition. Westinghouse has reviewed Reference 6 and applied the applicable portions to AP1000. It is noted that much of the criteria in Reference 6 is intended to determine the break locations that produce limiting amounts and compositions of debris that can be generated and transported to the screens. The criteria are applied consistent with PWR industry practice and in consideration of the unique AP1000 design features described below.

In the AP1000, different LOCA break locations do not generate different amounts and compositions of debris that are transported to the screens. The reason for this is that AP1000 does not use the types of insulation (such as fiberglass) that can be damaged by a LOCA jet and transported to the screens. Therefore debris generated by fibrous insulation is not a consideration in this analysis as stated in NUREG-1793. AP1000 uses MRI insulation in the location where it may be damaged by LOCA jets. The density of the MRI material ensures that any debris generated by the damage of this insulation material to settle in the containment sump and not be transported onto the screens.

The only debris that can be transported to the AP1000 screens post LOCA is resident debris. As a result, Westinghouse modified the selection criteria to determine the maximum amount of latent debris that can be transported to the containment recirculation, IRWST screens as well as to the core. Westinghouse determined the break locations that would transport the limiting amount of resident debris to the three different locations (recirculation screens, IRWST screens and core).

The following lists the three break locations that resulted in the limiting amount of debris to be transported to the three screens / core.

1. A loop compartment break, assumed to be a DVI line break at the reactor vessel. This break location produces the maximum debris for the core because the break becomes flooded and allows some debris to bypass the recirculation screens.

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 4: 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 5: 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 4 and 5 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 6. The upper bound amounts are referred to as the Bounding Case in Table 6.

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**
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). The purpose of the bench testing and calculation methods documented in WCAP-16530-NP was to characterize the type and quantity of precipitates formed using a chemical model evaluation, and to support the downstream effects evaluation using the chemical precipitates predicted in the chemical effects model. –These data and is methods haves been used to evaluate post-accident chemical affects and support sump screen performance testing for operating PWRs. These data and methods are applicable to the AP1000 for the following reasons;

1. The base chemical composition of the containment materials in the AP1000 was identified consistent with the classification groups listed in WCAP-16530-NP.
2. The sump temperature transient is within the bench test temperature range of 140 °F to 270 °F for more than 99.5% of the 30 days evaluated.
3. The sump pH transient for the AP1000 is within the range of 4.1 to 12.0 evaluated in WCAP-16530-NP.
4. The buffering agent for the PXS in the AP1000 plant is trisodium phosphate dodecahydrate (TSP) which was one of the buffering agents included in the bench testing.

Therefore, considering the above, the data and calculation methods described in WCAP-16530-NP are clearly applicable to the AP1000 design.

Table 7 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 7 also lists the chemical precipitants in terms of a mass concentration using the minimum recirculation water volume.

Table 7: 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.

Head Loss Calculations

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.

The head loss correlation used to evaluate the head loss across the AP1000 recirculation screens was the NUREG/CR-6224 correlation (Reference 5). The application of the NUREG/CR-6224 correlation is conservative for and applicable to the AP1000 for the following reasons:

- The NUREG/CR-6224 head loss correlation was developed for reactor building containment sump strainers with a contiguous fiber bed.
  - Several types of fibrous materials were used to construct the beds used in the development of NUREG/CR-6224 head loss correlation, including fiberglass.
  - The NUREG/CR-6224 head loss correlation was developed in a vertical loop with comparatively high velocity downward flow compressing the fibrous and particulate debris bed. For the AP1000 design, the recirculation screens would be vertical with low velocity flow through the screens that precludes debris bed compression observed in the testing used to develop the NUREG/CR-6224 head loss correlation.
- The only source of fibrous debris in the AP1000 design is from resident containment debris.
  - An evaluation of the deposition of expected resident fibrous debris for the AP1000 design on the recirculation screens determined that there was an insufficient volume of fibrous debris to develop a uniform fiber bed equal to or greater than the ⅛ inch depth generally accepted as needed for a contiguous fiber bed on a sump screen. See Table 9 below.
  - By the NRC Safety Evaluation on NEI 04-07 (Reference 6), the fibrous component of resident containment debris is treated as fiberglass.
  - Without a contiguous fiber bed, the AP1000 recirculation screens provide "clean screen" area; that is, there is recirculation screen area through which flow is unimpeded by a fibrous bed. This "clean screen" results in head losses lower than those predicted by the NUREG/CR-6224 head loss correlation.

Considering the items above, the NUREG/CR-6224 head loss correlation is not only applicable, but its application to the AP1000 design is conservative.

Two latent containment debris loading cases were evaluated:

1. The Bounding Case in Table 6 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 6). 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 8 provides the debris loadings used for the Sensitivity Case as compared with the Table 6 debris loadings.

Table 8: 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 9 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 9: 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 9 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. Also, as the AP1000 recirculation screens evaluation demonstrates that there is insufficient fiber available within the AP1000 containment to form ⅛ inch fiber bed on the recirculation screens, head loss testing of the AP1000 recirculation screens is unwarranted at this time.

AP1000 DOWNSTREAM EFFECTS EVALUATION

The term, "downstream effects" refers to effects of debris that is ingested through the recirculation screens on systems, structures and components located downstream of the recirculation screens. These effects are evaluated for operating plants to support closure of Generic Safety Issue GSI-191 using data and methods and developed by the PWR Owners Group. While AP1000 specific evaluations of downstream effects have not been completed, this section presents a description what work has been done and the methods that will be used to complete these evaluations, and their applicability to the AP1000 design.

Ex-Vessel Downstream Effects Evaluation Method

The data and methods that would be used to evaluate ex-vessel downstream effects would be Revision 1 of WCAP-16406-P (Reference 7). The evaluation methods identified in WCAP-16406-P Revision 1 that are applicable to long-term core cooling recirculation flow paths associated with the AP1000 design include:

- The fuel blockage evaluation as described in Section 5. This particular downstream effects evaluation method addresses the core evaluation from the NRC comment.
- Valve evaluations for plugging and erosive wear as described in Sections 7 and 8 and Appendix F. The screening criteria for valves that are identified in Revision 1 to WCAP-16406-P are generically applicable to valves in the long-term core cooling recirculation flow path of PWRs in general. Only the explosively actuated (squib) valves in the post-LOCA flow path are not covered by the screening criteria. Once the squib valves are open they exhibit, very closely, the characteristics of a standard gate valve.

There are design features of the AP1000 that eliminate the need for downstream effects evaluations of components that are included in Revision 1 of WCAP-16406-P. Evaluations excluded by the AP1000 design include:

- Pump evaluations, including hydraulic performance, disaster bushing performance, and vibration analysis. There are no safety related pumps in the AP1000 passive core cooling flow paths to evaluate.
- Heat exchanger evaluations for both plugging and erosive wear. There are no safety related heat exchangers in the AP1000 passive core cooling flow paths.
- Orifice evaluations for plugging and erosive wear as described in Sections 7 and 8 and Appendix F. There are no orifices in the post-LOCA recirculation flow path of the AP1000 design.
- Settling of debris in instrumentation lines as described in Section 8. There are no instrumentation lines used in the AP1000 post-LOCA containment recirculation flow path design that are required to support a safety related function.
- Containment Spray System (CSS). The AP1000 does not have a CSS that will be used during design basis post LOCA operations. It does have a containment spray feature that can be used during severe accident. Therefore, this system is excluded from consideration of the AP1000 design.

Thus, where applicable design features exist in the AP1000, the data and methods identified in Revision 1 of WCAP-16406-P may be applied to evaluate ex-vessel downstream effects for the AP1000 design.

Preliminary Ex-Vessel Downstream Effects Evaluation of AP1000 Recirculation Flow Paths

A preliminary assessment of ex-vessel downstream effects was accomplished by reviewing the process and instrumentation drawings (P&IDs) for the AP1000 PXS.

- For a postulated hot leg break, the post-LOCA recirculation flow path starts at containment recirculation screens A and B and proceeds through either a fully open motor operated gate valve or check valve and then to an 8 inch squib valve. The two trains then combine into a common header and flow through an open 8 inch motor operated gate valve. From the common header the flow splits nearly equally into two trains containing an 8 inch check valve followed by an 8 inch squib valve. The flow then combines into one of two Direct Vessel Injection (DVI) lines. From the DVI lines, coolant then flows through the DVI nozzle at the reactor vessel (which has an integral venturi), into the reactor vessel downcomer and downward into the reactor vessel lower plenum. From the lower plenum, coolant then passes through the core and out the hot legs either through the postulated break or the 4th stage ADS.
- For a cold leg break, the same flow path is utilized as in the hot leg case described above. However, it is possible due to the elevation of the AP1000 cold legs that, after depressurization and re-alignment, coolant will flow from the pool in the containment sump through the cold leg break and into the reactor vessel downcomer.

Based on this preliminary review of the P&IDs and excluding the reactor core, the minimum flow dimension in either of these flow paths downstream of the recirculation screens and upstream of the core is 4 inches; this location is the venturi in the DVI line nozzle at the reactor vessel. With a characteristic dimension (hole diameter) of the recirculation screen of 0.125 inches or less, and using the guidance of WCAP-16406-P, the maximum deformable debris size that could be ingested through the recirculating screens is about 0.20 inches. Considering the light debris loading described earlier in this report along with the large dimensions of the recirculating flow path relative to the debris size to be considered, the preliminary conclusion of an ex-vessel downstream effects evaluation suggests that there would be no adverse affects due to debris bypassed by the recirculation screens.

In-Vessel (Core) Downstream Effects Evaluation Method

With respect to fibrous / particulate debris and downstream effects associated with the core, this report contains an evaluation of the impact on core cooling of a DVI LOCA which results in significant latent debris entering the reactor vessel by bypassing the recirculation screens. The results of this evaluation indicate that for the AP1000 this debris does not adversely affect core cooling. This case is expected to bound the small additional debris that might leak through the recirculation screens during an downstream effects evaluation.

With respect to chemical products and downstream effects associated with the core, the potential for deposition of post-LOCA chemical products on the fuel cladding and the consequential effects on clad temperatures can be addressed using the methods developed and documented in WCAP-16793-NP (Reference 8). This evaluation method was developed to be generically applicable to all PWRs.

WCAP-16793-NP provides a sample calculation of the post-LOCA chemical deposition on fuel cladding. The input parameters for the sample calculation were selected to represent challenging conditions for current PWRs. The results of the calculation demonstrate acceptable long-term core coolant and clad temperatures.

Given the small post-LOCA chemical effects associated with the AP1000 compared to current PWRs and the sample calculation, it is expected that the chemical deposition of post-LOCA chemical effects on fuel cladding for the AP1000 will be less than those predicted in the sample calculation of WCAP-16793-NP.

Rigorous evaluations of ex-vessel and in-vessel downstream effects are being planned and performed for the AP1000 design. The data and methods given in References 7 and 8 are applicable to the AP1000 design and will be used to perform these evaluations, and the results of these evaluations documented.

ONGOING GSI-191 REGULATORY ACTIVITIES

It is recognized that there is ongoing regulatory activity associated with the closure of GSI-191. This ongoing activity will be monitored for potential applicability to the AP1000 design.

References

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. NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," October 1995
6. NEI 04-07, Revision 0 "Pressurized Water Reactor Sump Performance Evaluation Methodology", December 2004

7. WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," September 2007
8. WCAP-16793-NP, Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," June 2007
9. NUREG-1793, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design," September 2004

REGULATORY IMPACT

Design Function

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.

Severe Accident Change Criteria

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.

Security

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

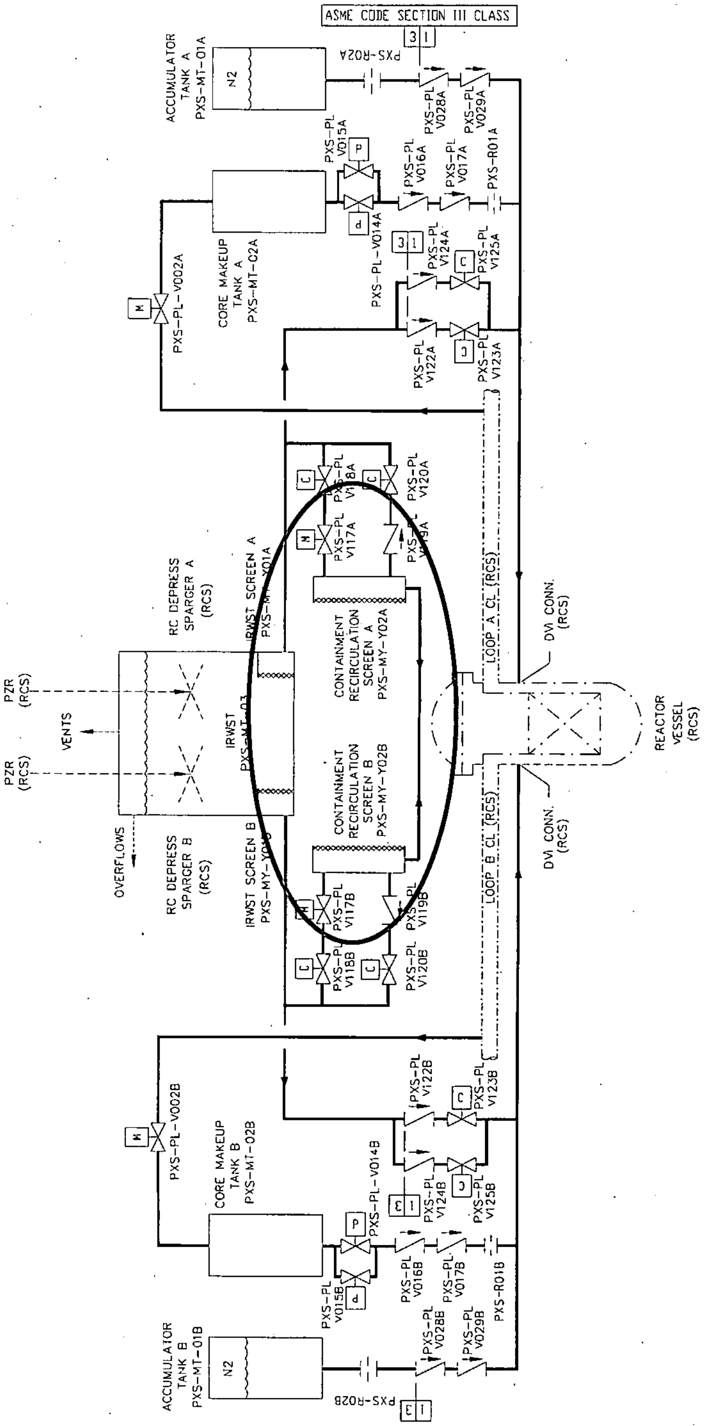
The following revised DCD sections are included:

Tier 1:
- ITAACS Table 2.2.3-4
- Figure 2.2.3-1 (Sheet 2 of 2)
- Figure 3.3-5

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)

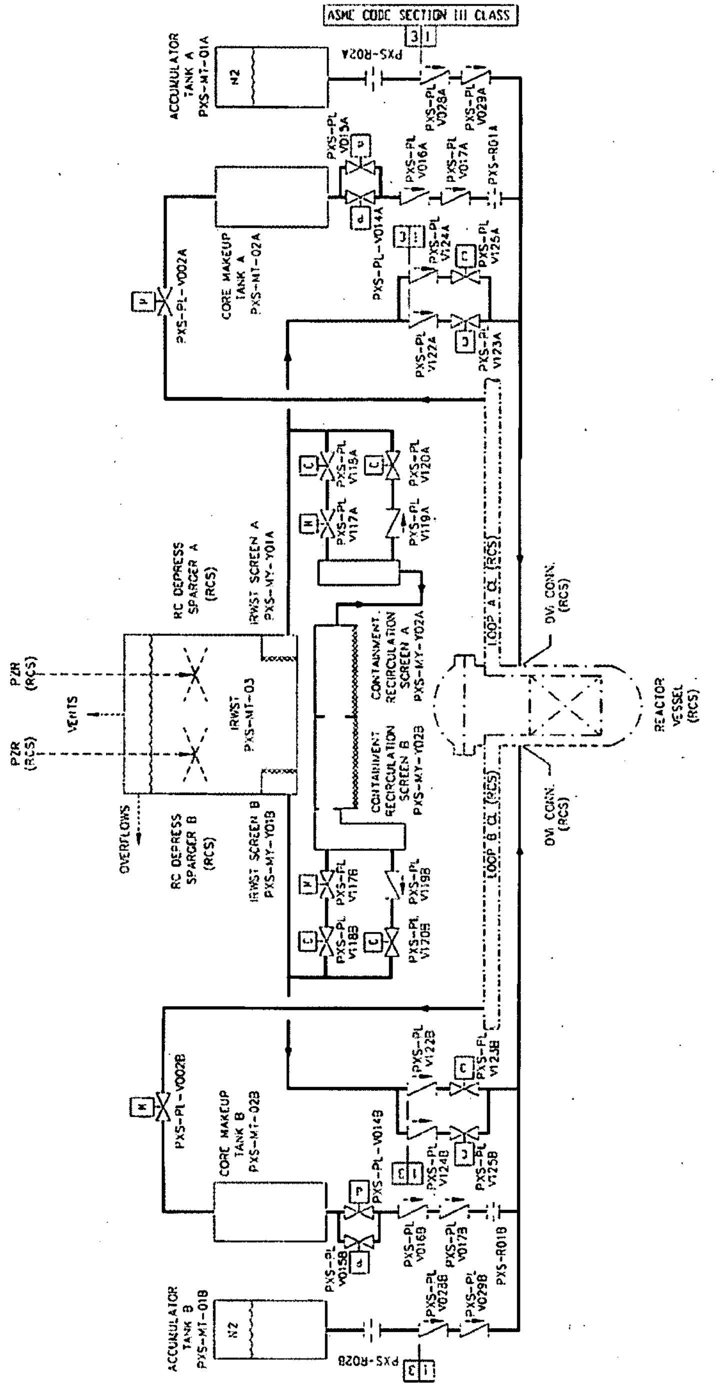
Table 2.2.3-4 (cont.)
Inspections, Tests, Analyses, and Acceptance Criteria

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 ≥ 70 ft² and~~ of each ~~fine~~ IRWST screen is ≥ 500 ft² ~~140 (unfolded area)~~. The screen surface area of each containment recirculation screen is ≥ 2500 ft². The bottom of the containment recirculation screens is ≥ 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 ≥ 100 lb/ft³.
	xi) Inspection of the as-built CMT inlet diffuser will be conducted.	xi) The CMT inlet diffuser has a flow area ≥ 165 in².
	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" ± 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

SRI

Security-Related Information, Withhold Under 10 CFR 2.390

Figure 3.3-5
Nuclear Island Plan View at Elevation 96′-6″

Current DCD Figure Showing Area to be Revised

SRI

Security-Related Information, Withhold Under 10 CFR 2.390

Figure 3.3-5
Nuclear Island Plan View at Elevation 96′-6″

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 a ~~A~~debris curb function~~located~~ at the base of the IRWST screens to prevent~~s~~ 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 sufficient~~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 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 rackto 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.

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Figure 1.2-6

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

Current DCD Figure Showing Area to be Revised

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Figure 1.2-6

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

Revised DCD Figure

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Figure 1.2-9

**Nuclear Island General Arrangement
Plan at Elevation 117'-6" with Equipment**

Current DCD Figure Showing Area to be Revised

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Figure ~~1.2-9~~

Nuclear Island General Arrangement

Plan at Elevation 117′-6″ with Equipment

Revised DCD Figure

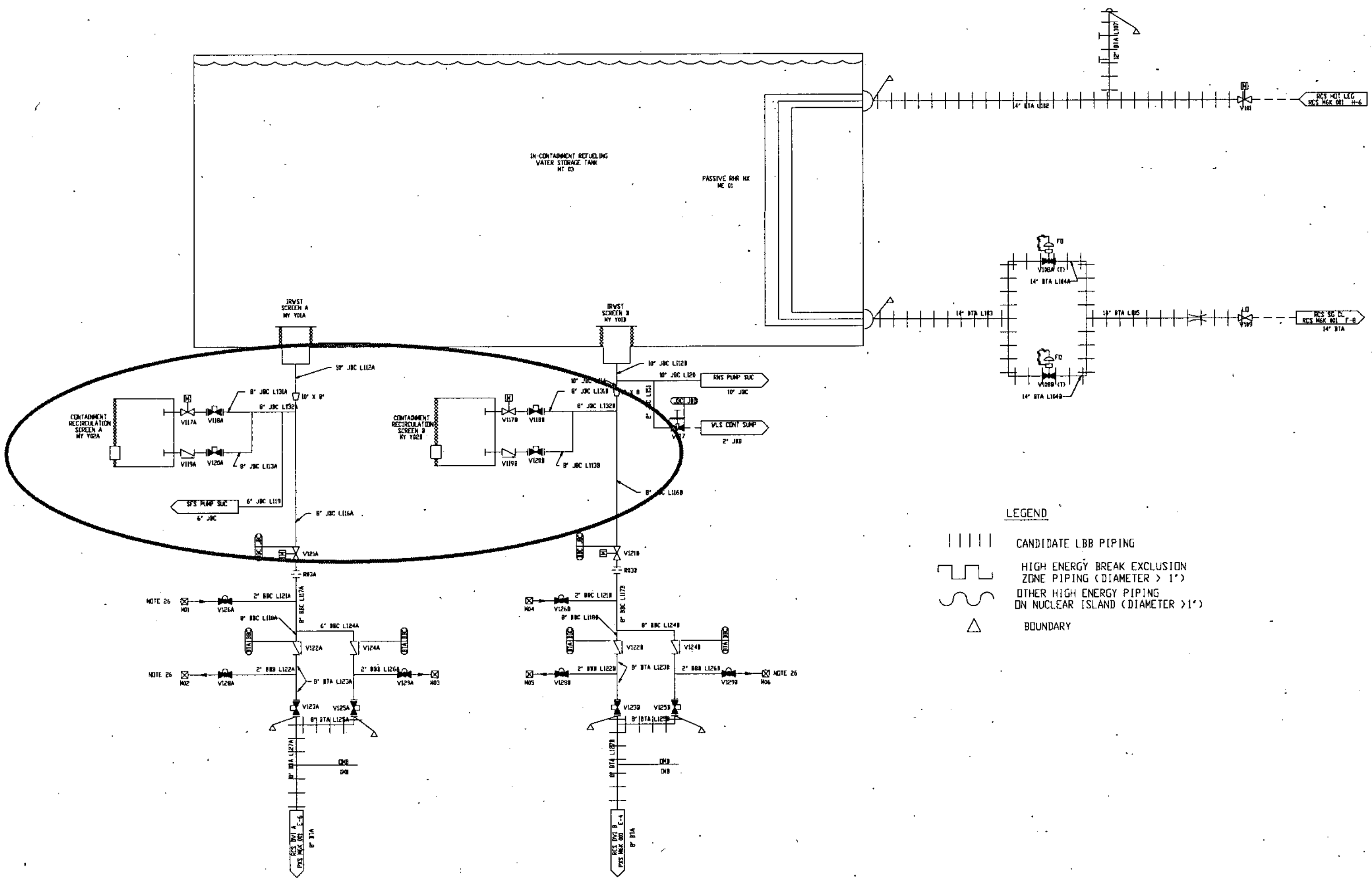


Figure 3E-4 (Sheet 2 of 2)
High Energy Piping – Passive Core Cooling System

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

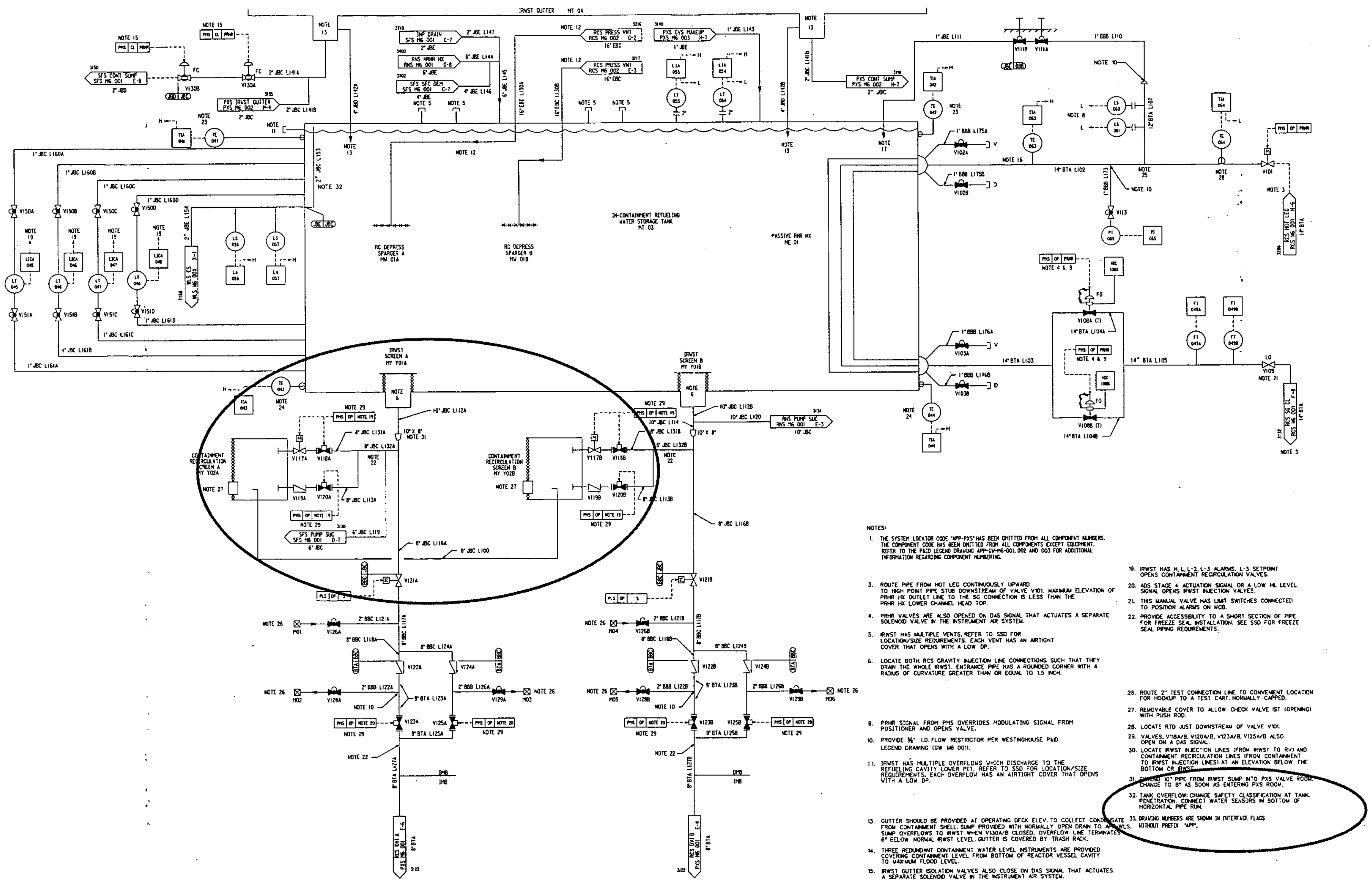


Figure 6.3-2

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

Current DCD Figure Showing Areas to be Revised

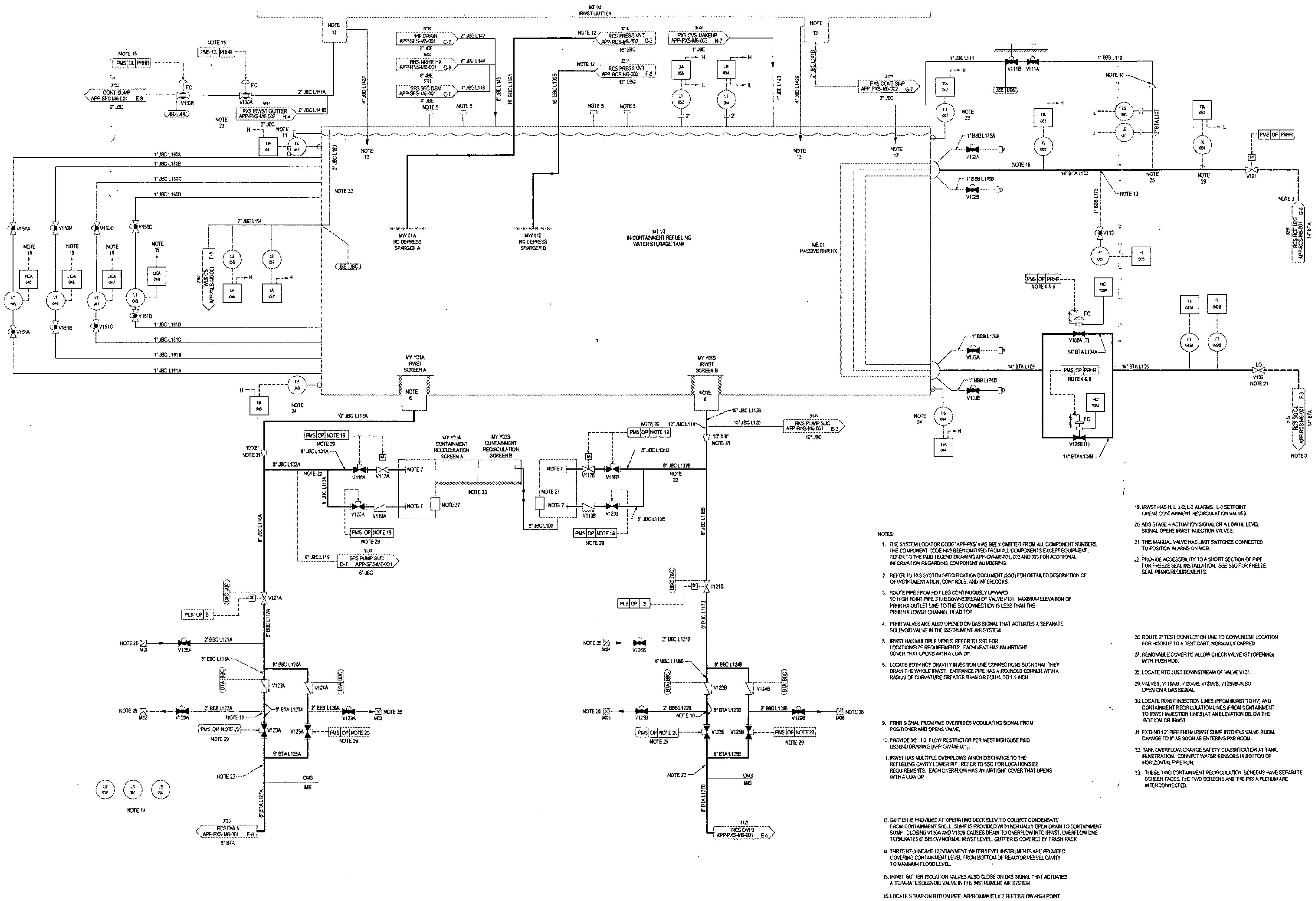
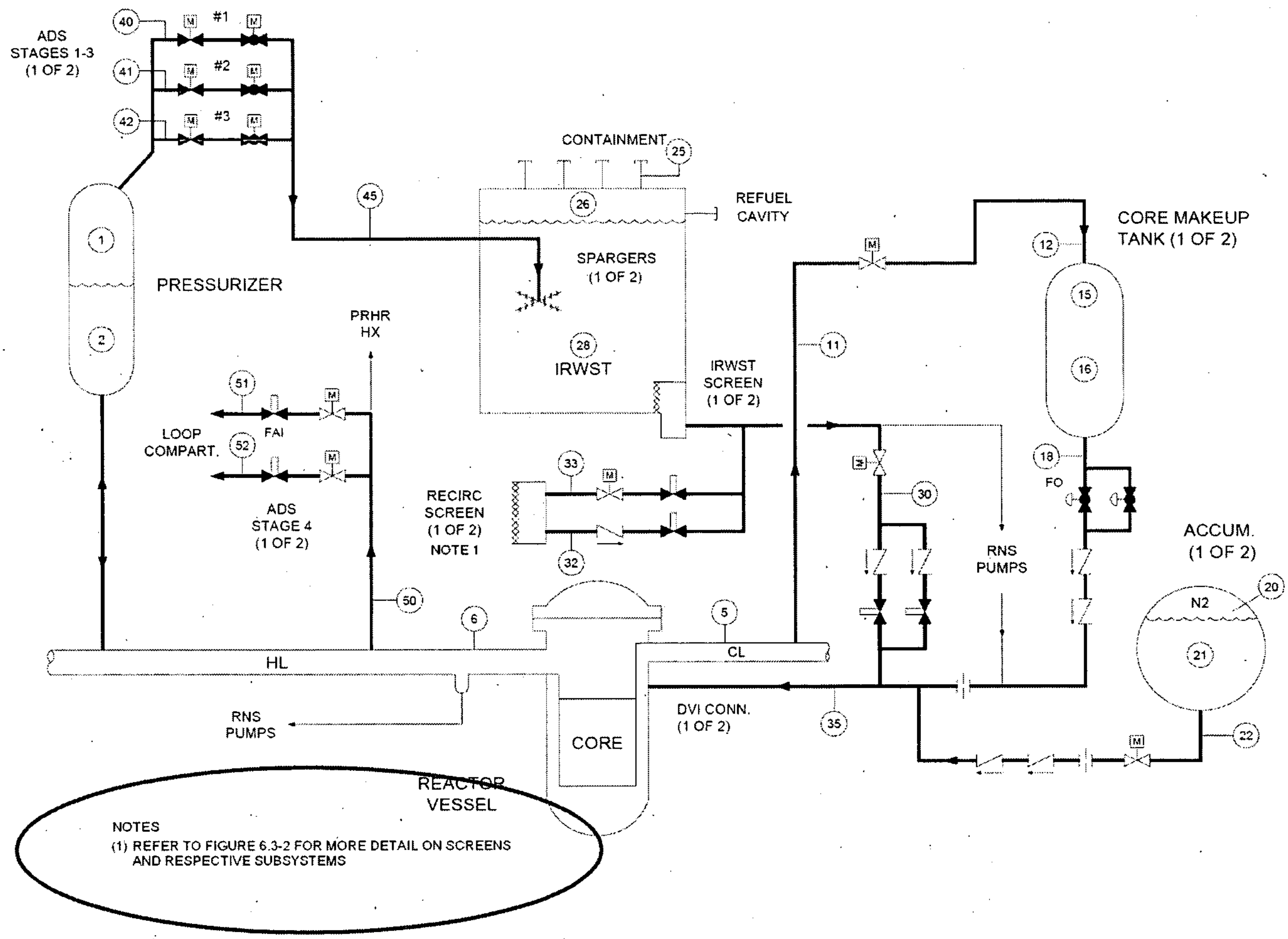


Figure 6.3-2
Passive Core Cooling System
Piping and Instrumentation Diagram (Sheet 2)

Revised DCD Figure



Inside Reactor Containment
Figure 6.3-3

Passive Safety Injection (REF) RCS & PXS

Revised DCD Figure with addition circled.

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Figure 6.3-6

IRWST Screen Plan Location

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Figure 6.3-6

IRWST Screen Plan Location

Revised DCD Figure

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Figure 6.3-7

IRWST Screen Section Location

Current DCD Figure Showing Area to be Revised

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Figure 6.3-7

IRWST Screen Section Location

Revised DCD Figure

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Figure 6.3-8

Containment Recirculation Screen Location Plan

Current DCD Figure

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Figure 6.3-8

Containment Recirculation Screen Location Plan

Revised DCD Figure

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Figure 6.3-9

Containment Recirculation Screen Location Elevation

Current DCD Figure

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Figure 6.3-9

Containment Recirculation Screen Location Elevation

Revised DCD Figure

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Figure 9A-1 (Sheet 4 of 16)

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

Current DCD Figure Showing Area to be Revised

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Figure 9A-1 (Sheet 4 of 16)

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

Revised DCD Figure

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Figure 12.3-1 (Sheet 5 of 16)

Current DCD Figure Showing Area to be Revised

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

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Figure 12.3-1 (Sheet 5 of 16)

Revised DCD Figure

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

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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

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Figure 12.3-2 (Sheet 5 of 15)

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

Revised DCD Figure

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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

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Figure 12.3-3 (Sheet 5 of 16)
Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 96′-6″

Revised DCD Figure

ENCLOSURE 3

Responses to NRC letter dated August 22, 2007

Response to NRC Letter Dated August 22, 2007;
Issuance of Technical Report TR 26

Acceptance Issue #1

Down stream effects in the core are not addressed in TR 26. During the July 27, 2007 conference, Westinghouse acknowledged that the issue was not addressed and also stated that Westinghouse would probably not be able to rely on information that is currently under review for operating reactors.

Response:

The statement regarding the downstream effects in the core being addressed in TR 26 is partially correct; TR 26 does not address effects downstream of the containment sump screen for equipment, instrumentation, or the core. During the 7/27/07 conference call Westinghouse said that the AP1000 would be less vulnerable to downstream effects on the PXS recirculation piping system than current operating plants. Westinghouse agreed to perform a study of these effects in AP1000. For the core, TR 26 already includes an evaluation TR 26 of a scenario of a DVI line break where approximately 60% of the recirculation flow and resident debris bypasses the screen through the break. This situation is unique to AP1000 and the results of the evaluation showed that even with this amount of recirculation flow bypassing the screens there is not enough debris to form a contiguous fiber bed on the bottom of the core and therefore clean "screen" area still exists on the bottom nozzle of the fuel. It is determined that this calculation would bound a calculation that determined the amount of debris that can bypass the screen by flowing through it because the assumption value for bypass of the screen is much lower than this.

During the above conference call we disagreed with the statement that, "Westinghouse would probably not be able to rely on information that is currently under review for operating reactors." We said that applicable portions of information that is currently under review could be applied to evaluate downstream effects for the AP1000 design.

The document that would be used to evaluate ex-vessel downstream effects would be Revision 1 of WCAP-16406-P (Reference 1). The evaluation methods identified in WCAP-16406-P Revision 1 that are applicable to long-term core cooling recirculation flow paths associated with the AP1000 design include:

- The fuel blockage evaluation as described in Section 5. This particular downstream effects evaluation method addresses the core evaluation from the NRC comment.
- Valve evaluations for plugging and erosive wear as described in Sections 7 and 8 and Appendix F. The screening criteria for valves that are identified in Revision 1 to WCAP-16406-P are generically applicable to valves in the long-term core cooling recirculation flow path of PWRs in general. Only the explosively actuated (squib) valves in the post-LOCA flow path are not covered by the screening criteria. The squib valves will open before debris can reach them, and furthermore the squib valves are only required to open to perform their safety function. Once the squib valves are open they exhibit, very closely, the characteristics of a straight through gate valve, for this reason Westinghouse does not feel the squib valves will cause plugging.

There are design features of the AP1000 that eliminate the need for downstream effects evaluations, including those identified in Revision 1 of WCAP-16406-P and include:

- Pump evaluations, including hydraulic performance, disaster bushing performance, and vibration analysis. There are no safety related pumps in the AP1000 passive core cooling flow paths to evaluate.

- Heat exchanger evaluations for both plugging and erosive wear. There are no safety related heat exchanges in the AP1000 passive core cooling flow paths.

- Orifice evaluations for plugging and erosive wear as described in sections 7 and 8 and Appendix F. The post-LOCA recirculation flow path of the AP1000 design contains no orifices in the PXS.

- Settling of debris in instrumentation lines as described in Section 8. There are no instrumentation lines used in the AP1000 post LOCA recirculation flow path design that are required to support a safety related function.

With respect to downstream effects associated with the core, the potential for deposition of post-LOCA chemical products on the fuel cladding and the consequential effects on clad temperatures can be addressed using the methods developed and documented in WCAP-16793-NP. This is a relatively new evaluation method developed to be generically applicable to all PWRs.

The evaluation contained in TR 26 of the DVI LOCA which results in significant bypass of the recirc screens is expected to bound the small additional debris that might leak through the recirc screens during a downstream effects evaluation.

Thus, information and evaluation methods that are currently under review in References 1 and 2 for operating reactors are also applicable to the AP1000 design. Westinghouse is currently developing a downstream effects evaluation for the AP1000 nuclear power plant using these methods.

Acceptance Issue #2

Westinghouse did not adequately justify the adequacy of the sump screens. Westinghouse did not reference a specific head loss correlation and did not conduct head-loss tests. When the head loss correlation was discussed, Westinghouse described the head loss correlation but was not able to establish its applicability to the AP1000. Westinghouse would need to establish applicability to the AP1000 or conduct head loss tests with a prototypical model.

<u>Response</u>:

The head loss correlation used to evaluate the head loss across the AP1000 recirculation screens was the NUREG/CR-6224 correlation (Reference 3). The application of the NUREG/CR-6224 correlation is conservative for and applicable to the AP1000 for the following reasons:

- The NUREG/CR-6224 head loss correlation was developed for reactor building containment sump strainers with a contiguous fiber bed.
  - Several types of fibrous materials were used to construct the beds used in the development of NUREG/CR-6224 head loss correlation, including fiberglass.
  - The NUREG/CR-6224 head loss correlation was developed in a vertical loop with comparatively high velocity downward flow compressing the fibrous and particulate debris bed. For the AP1000 design, the recirculation screens would be vertical with low velocity flow through the screens that precludes debris bed compression observed in the testing used to develop the NUREG/CR-6224 head loss correlation.
- The only source of fibrous debris in the AP1000 design is from resident containment debris.
  - An evaluation of the deposition of expected resident fibrous debris for the AP1000 design on the recirculation screens determined that there was an insufficient volume of fibrous debris to develop a uniform fiber bed equal to or greater than the ⅛ inch depth generally accepted as needed for a contiguous fiber bed on a sump screen.
  - By the NRC Safety Evaluation on NEI 04-07 (Reference 4), the fibrous component of resident containment debris is treated as fiberglass.
  - Without a contiguous fiber bed, the AP1000 recirculation screens provide "clean screen" area; that is, there is recirculation screen area through which flow is unimpeded by a fibrous bed. This "clean screen" results in head losses lower than those predicted by the NUREG/CR-6224 head loss correlation.

Considering the items above, the NUREG/CR-6224 head loss correlation is not only applicable, but its application to the AP1000 design is conservative.

The final design of the recirculation screens has not been determined for the AP1000 design. For the recirculation screen sizes used in the evaluation of the AP1000, it has been demonstrated that there is insufficient fiber available within the AP1000 containment to from ⅛ inch fiber bed on the recirculation screens. Therefore, considering the low fiber load provides for "clean screen" area, testing of the AP1000 recirculation screens is unwarranted until a final design for those screens is selected.

Acceptance Issue #3

Westinghouse has referenced information regarding chemical effects that is currently under review for operating reactors. The applicability of this information to AP1000 has not been established.

Response:

The chemical effects report alluded to in NRC's letter of August 22, 2007 is WCAP-16530-NP (Reference 6). The report documents chemical effects bench testing. The purpose of WCAP-16530-NP bench testing was to characterize the type and quantity of precipitates formed using a chemical model evaluation, and to support the downstream effects evaluation using the chemical precipitates predicted in the chemical effects model. WCAP-16530-NP is applicable to the evaluation the chemical effects for AP1000 for the following reasons:

1. The base chemical composition of the containment materials in the AP1000 was identified consistent with the classification groups listed in WCAP-16530-NP.

2. The sump temperature transient is within the bench test temperature range of 140 °F to 270 °F for more than 99.5% of the 30 days evaluated.

3. The sump pH transient for the AP1000 is within the range of 4.1 to 12.0 evaluated in WCAP-16530-NP.

4. The buffering agent for the PXS in the AP1000 plant is trisodium phosphate dodecahydrate (TSP) which was one of the buffering agents included in the bench testing.

Therefore, considering the above, the data and calculation methods described in WCAP-16530-NP are clearly applicable to the AP1000 design.

Acceptance Issue #4

Westinghouse has not described the break selection criteria.

Response:

The industry has provided guidance in Reference 4 for the selection of break locations within a pressurized water reactor (PWR) and its effect on debris generation. Reference 4 recommends break locations be parametrically evaluated for:

1. Generation of the maximum amount of debris that is transported to the sump screen
2. Generation of the worst combination of debris mixes that are transported to the sump screen

Westinghouse has considered the application of this guidance to the AP1000 design. The AP1000 design provides for only source of insulation debris to be metal reflective insulation (MRI) which does not transport to the recirculation sump screens. The use of high-density coatings in combination with containment design features minimizes coatings debris that may be transported to the recirculation sump screens. The only debris that will be transported to the screens would be resident or latent containment debris. Since the only debris source is resident or latent containment debris, Westinghouse therefore selected breaks to ensure the maximum amount of resident or latent containment debris is evaluated to reach the containment recirculation and IRWST screens, as well as the core. Further explanation of the break location selection criteria has been added to technical report 26 Revision 2.

Acceptance Issue #5

Westinghouse has not explained how flow velocities were calculated and has not justified the non-transport of all unqualified coatings and qualified coatings in the zone of influence.

Response:

Reference 5 page 6-51 states that the transport of coatings to the screens is not expected because the use of high density epoxy coatings and the use of a protective plate just above the recirculation screens in the AP1000 design prevents coating chips from falling or floating into the area in front of the screens. This combination of features with the low flow rates discussed in reference 5 on pages 6-48 and 6-49 address the issue of flow velocities and the non-transport of unqualified coatings to the screens. It should be noted that the DCD Revision 16 (Reference 8) has 55% more recirculation screen face area and as a result will have lower velocity which further reduces the chance that coating debris could be transported to these screens.

Acceptance Issue #6

Westinghouse has not justified the loss of redundancy in the screen design.

Response:

DCD Revision 15 (Reference 7) has a cross connection between the two recirculation screens. This feature was adopted to ensure that in all cases including a DVI line break that both screens would function in a LOCA. This feature doubles the screen area and significantly increases the margin with respect to flow blockage. The NRC has reviewed and accepted this feature as part of the AP1000 design.

In DCD Revision 16 (Reference 8) the main change in the screen arrangement was to significantly increase the recirculation screen areas (from 280 ft2 to 5000 ft2 total). As a result of making these screens much larger they have grown together such that they butt up against each other. Redundancy in screen design is maintained by the physical separation of the two identical screens. While the two screens are spatially next to each other, the screens themselves are separated by a partition that allows communication between the two screens.

Also, the containment cleanliness program is required to preclude large items (tarps, plastic sheets, etc.) that could block large areas of screen. With the larger face area now provided the possibility of the blocking a large percentage of the screen is significantly reduced. Note that damage (penetration) of screens as a consequence of a LOCA is unacceptable in not only AP1000, but all PWR plants; the AP1000 design uses perforated steel plates instead of fine mesh screen to preclude damage by penetration.

References

1. WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," September 2007
2. WCAP-16793-NP, Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," June 2007
3. NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," October 1995
4. NEI 04-07, Revision 0 "Pressurized Water Reactor Sump Performance Evaluation Methodology", December 2004
5. NUREG-1793, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design," September 2004
6. WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," February 2006
7. APP-GW-GL-700, "AP1000 Design Control Document", Revision 15, November 2005
8. APP-GW-GL-700, "AP1000 Design Control Document", Revision 16, May 2007