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February 17, 2011

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-11037

Subject: **MHI's Responses to US-APWR DCD RAI No.681-5257 Revision 2 (SRP 19.0)**

References: 1) "Request for Additional Information No. 681-5257 Revision 2, SRP Section: 19 – Probabilistic Risk Assessment and Severe Accident Evaluation," dated January 20, 2011.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 681-5257 Revision 2".

Enclosed are the responses to all of the RAIs that are contained within Reference 1.

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of the submittals. His contact information is below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure:

1. Responses to Request for Additional Information No. 681-5257 Revision 2

CC: J. A. Ciocco
C. K. Paulson

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Enclosure 1

UAP-HF-11037
Docket Number 52-021

Responses to Request for Additional Information No.681-5257
Revision 2

February, 2011

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

02/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No.52-021

RAI NO.:	**NO. 681-5257 REVISION 2**
SRP SECTION:	**19 – Probabilistic Risk Assessment and Severe Accident Evaluation**
APPLICATION SECTION:	**19**
DATE OF RAI ISSUE:	**01/20/2011**

QUESTION NO. : 19-495

The US-APWR frequency of overdraining the RCS to reach midloop conditions is reported as approximately 3E-6 per calendar year assuming midloop will be entered twice in each refueling outage per 24 month cycle. This reduction, which is orders of magnitude lower than current PWR operating data, is based on (1) failure of automatic isolation of CVS on low hot leg level and (2) failure of the operator to terminate the drain down if the automatic isolation fails. The staff has the following questions:

(a) In order for the staff to evaluate the human error probability, MHI is requested to document in Chapter 19 and Section 5.4.7.2.3.6 of the DCD (1) the hot leg level/set point at which this automatic isolation is supposed to occur and (2) the highest hot leg level at which the RHR pumps are expected to fail due to air ingestion given a RHR flow rate of 2650 gpm required by TS surveillance testing.

(b) In the last paragraph on page 5.4-45, it is stated that higher RCS level reduces the possibility of air entrainment during midloop, which is reported as approximately 4 inches above hot leg midplane. This increased margin to air entrainment has no basis since operating PWRs maintain RCS hotleg levels within inches to the level that vortexing initiates. Please remove this statement or please provide the analysis which documents the hotleg levels at which vortexing initiates and becomes fully developed for the highest flow rate anticipated for midloop operation.

ANSWER:

(a)

Set points at which automatic isolation for low-pressure letdown line actuates will be documented in Subsection 5.4.7.2.3.6 and Chapter 19.

Figure 19.495-1 shows the postulated images of RCS water level with water level for automatic isolation of low-pressure letdown line and for CS/RHR pump surveillance testing. The automatic isolation for the low-pressure letdown line is initiated by detection of the RCS Low water level signal, which actuates when the RCS water level is below 0.47 feet above the loop center.

Also, TS surveillance testing for CS/RHR pump is performed when the RCS water level is between RCS Low water level (0.47 feet higher than loop center) and RCS High water level.(2.07 feet higher than loop center). The high SG installation elevation of the US-APWR design can keep RCS water level higher than loop center during SG maintenance and hydrogen peroxide operation. The design enables the RCS water level to be maintained higher than 0.33 feet above the loop center for all modes of RHR operation. RHR operation conducted under RCS water level higher than 0.33 feet above the loop center at 2,650 gpm does not cause air ingestion based on operating plant experience. CS/RHR pump surveillance testing with a flow rate of 2,650 gpm can be performed without air ingestion.

Failure probability of operator action to manually isolate the low-pressure letdown line has small impact on the total CDF during LPSD operation because this operator action is a recovery action to cope with failure of the automatic isolation. If human error probability of the action is assumed to be 10 times the base case (failure probability of the action used in base case = 3.8E-03), the total CDF is approximately 1% higher than the base case CDF. Uncertainty associated with the reliability of this operator action has small impact on the PRA results.

(b)
This is a general description because it is obvious that increasing the water level reduce the possibility of vortexing initiation. But as this description may be confusing, the last paragraph of Subsection 5.4.7.2.3.6 will be revised as shown in "Impact on DCD".

Impact on DCD
Subsection 5.4.7.2.3.6 will be revised as follows:

D. Interlock for abnormal water level decrease
When the water level of RCS drops below the RCS Low water level (0.47 feet higher than loop center) ~~mid-loop level~~, low pressure letdown lines are isolated automatically. This interlock is useful to prevent loss of reactor coolant inventory

(Last paragraph of 5.4.7.2.3.6)
The level in the primary system is lowered below the upper end of the hot and cold legs. The RCS water level should be maintained higher than 0.33 feet above the loop center and the RHR flow of 1,550 to 2,650 gpm should be supplied. ~~During mid-loop operation, the air/water interface is at close proximity to the RHR suction nozzles located on the hot legs, but the higher RCS water level applied for the US-APWR design reduces the possibility of air entrainment into the RHR pump suction. Air ingestion by an RHR pump can cause loss of pump function, creating the potential for loss of RHR.~~

Subsection 19.1.6.1 and Table 19.1-119 will be revised in accordance with the response.

(Page 19.1-109, Fourth paragraph in Loss of RHR due to over-drain)
These valves are automatically closed by detection of RCS low water level signal which

actuates when the RCS water level is 0.47 feet higher than loop center, and the CVCS is isolated from the RHRS by the RCS loop low-level signal to prevent loss of RCS inventory at mid-loop operation during plant shutdown.

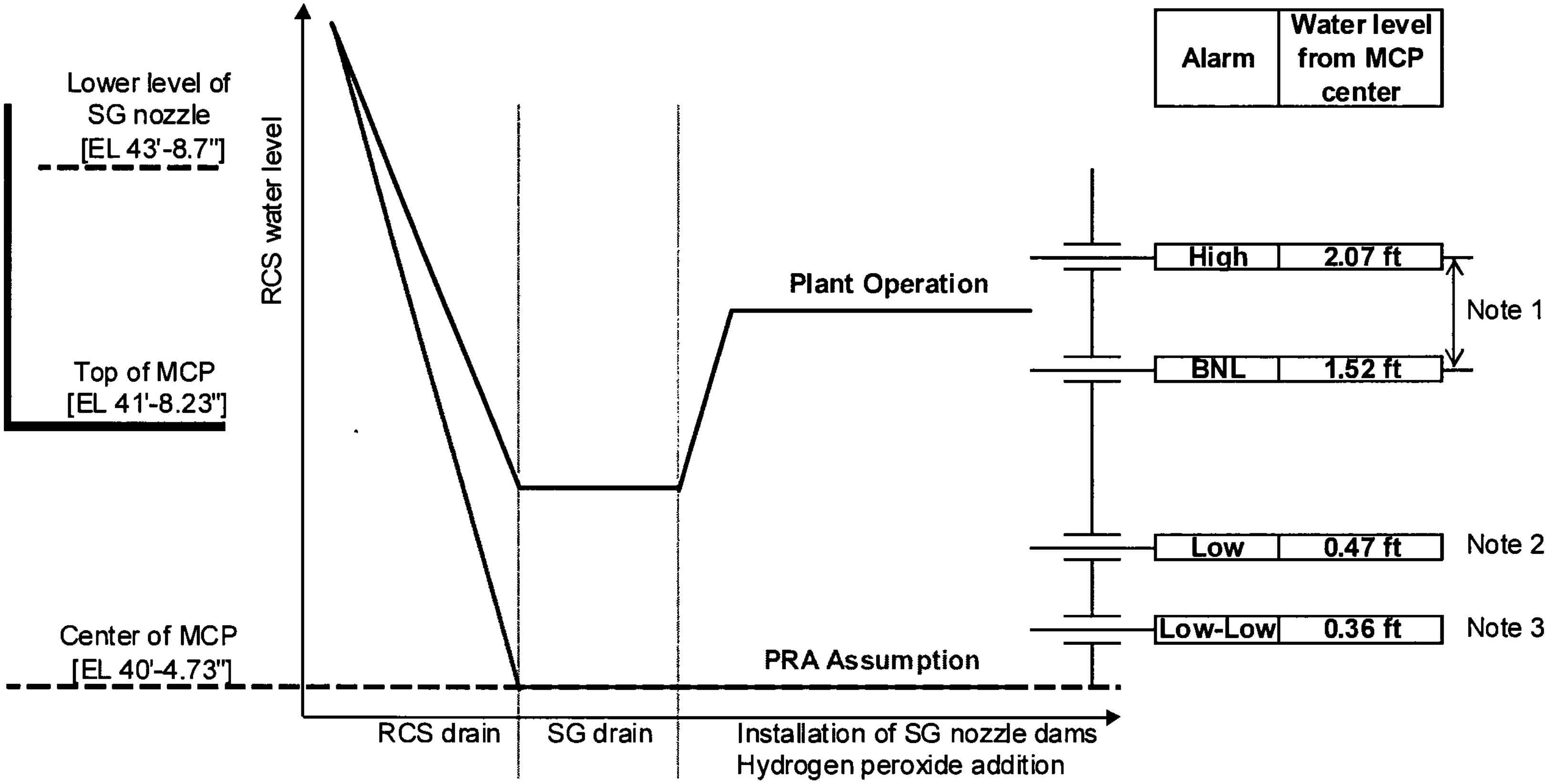
(Page 19-1-110, Third paragraph in Loss of RHR caused by falling to maintain water level)
If the charging injection system or the letdown line system fail and the low-pressure letdown isolation valve fail to close after RCS water level ~~has decreased to the level of the RV nozzle center~~ is below the set point for the isolation of low-pressure letdown, FLML is assumed to occur. Since POS 4-1 and POS 8-1 is the beginning of mid-loop operation, and RCS water level is decreasing and is not kept constant, it is assumed that this FLML event is not applicable. On the other hand, in POS 4-2, POS 4-3, POS 8-2 and POS 8-3, FLML is considered as an initiating event.

Table 19.1-119 Key Insights and Assumptions (Sheet 3 of 23)

Key Insights and Assumptions	Dispositions
- The RHR system is used to provide core cooling when the RCS must be partially drained to allow maintenance or inspection of the reactor head, SGs, or reactor coolant pump seals.	5.4.7.2.3.6
- During mid-loop operation, if the water level of RCS drops below ~~the mid-loop level~~ RCS low water level, low pressure letdown lines are isolated automatically. This interlock is useful to prevent loss of reactor coolant inventory.	5.4.7.2.3.6
5. Refueling Water Storage Pit	
- The RWSP is located on the lowest floor inside the containment. The coolant and associated debris from a pipe or component rupture (LOCA), and the containment spray drain into the RWSP through transfer pipes.	6.3.2.2.5
- Four independent sets of ECC/CS strainers located in the RWSP. The strainer design includes redundancy, a large surface area to account for potential debris blockage and maintain safety performance, corrosion resistance, and a strainer hole size to minimize downstream effects.	6.3.2.2.6

Impact on R-COLA and S-COLA.
There is no impact on R-COLA and S-COLA.

Impact on PRA
There is no impact on PRA.



Note

1. RCS water level during normal operating excluding SG drain is between BNL and High.
2. Low signal actuates automatic isolation for low-pressure letdown line.
3. Low-Low signal alerts initiation of gravity injection.
4. Testing for containment spray/residual heat removal (CS/RHR) pumps is performed at above Low water level.

MCP: main coolant piping
BNL: below normal level

Figure 19.495-1 RCS Water Level Transition

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

02/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No.52-021

RAI NO.:	**NO. 681-5257 REVISION 2**
SRP SECTION:	**19 – Probabilistic Risk Assessment and Severe Accident Evaluation**
APPLICATION SECTION:	**19**
DATE OF RAI ISSUE:	**01/20/2011**

QUESTION NO. : 19-496

In a July 10, 2009, response to RAI 369, Question 19-336, the applicant committed to add the operator actions for reflux cooling to DCD Table 19.1-119. These operator actions are described in assumption 14, page 19.1-961 of the DCD. However, closure of the pressurizer vent valve in POS 4-1 or other RCS penetrations was not included in this assumption. The staff is requesting MHI to state in this assumption that successful SG cooling requires; (1) a closed RCS, (2) assurance that temporary RCS boundaries such as SG nozzle dams will not fail as a result of RCS pressurization (3) SG inventory by motor driven EFW, and (4) a SG depressurization valve to remove decay heat. To prevent confusion with the COL applicant, the staff requests that this assumption should also state, " In accordance with GL 88-17, the staff recommends that licensees consider removing a pressurizer manway (if analysis shows this to provide a sufficient vent path) or otherwise creat a suitable opening to limit the pressurization which could follow loss of DHR while SG nozzle dams and the reactor vessel head are in place."

ANSWER:

The assumption (1) to close the pressurizer vent valve will be documented in the operator actions of Table 19.1-119. However, assumption (2) regarding temporary RCS boundaries such as SG nozzle dams will not be documented in the table. (Assumptions to (3) manually start motor-driven EFW pump and (4) open main steam depressurization valve (MSDV) are already included in Table 19.1-119) The basis is as follows:

Decay heat removal via SGs considered in LPSD PRA is categorized into two types: one is performed at RCS full water level, and the other is performed at de-elevated RCS water level. The former is applicable to POSs 3, 9 and 11 and is the same as the mitigation function considered in at-power PRA because there is sufficient coolant in the RCS. Then, heat removal via SGs can be performed by starting motor-driven EFW pump and opening MSDV (Assumptions (3) and (4) in **QUESTION**), regardless of a closed RCS (Assumption (1)

QUESTION). On the other hand, the latter is applicable to POSs 4-1 and 8-3 (i.e., RCS draining/supplying or mid-loop operation) and is SG reflux cooling. In this case, not only starting the EFW pump and opening MSDV but also closing the RCS vent is required for heat removal via SGs. The US-APWR considers that the pressurizer spray vent valve is open as a RCS vent path for RCS draining. In the response to No.19-45 of RAI #39-548, it is demonstrated that if the valve is kept open, RCS inventory will be lost via the vent path to containment and result in core uncovery approximately 20 hours after a loss of RHR. The result implies the operator action to manually close pressurizer vent valve is necessary to maintain SG reflux cooling while the RCS is not full and is at the open state.

Assumption (2) in **QUESTION** does not apply to operability of SG reflux cooling. The US-APWR considers that SG nozzle dams are installed at the beginning of POS 4-3 and removed at the end of POS 8-1. During these POSs, SG reflux cooling is assumed to be guaranteed failure because there is a large RCS vent due to removal of pressurizer safety valves. For other POSs, there is also a large RCS vent path due to removal of SG manways, and SG reflux cooling is unavailable. .

The US-APWR assumes that the pressurizer safety valves are removed while SG nozzle dams and the reactor vessel head are placed in accordance with GL 88-17. The response to No.19.493 of RAI #669-5219 has discussed that the assumption will be documented in Subsection 5.4.7.2.6.3 and Table 19.1-119. Also, analysis results using MAAP code show that the SG nozzle dams is designed to withstand RCS pressurization caused by a loss of DHR while pressurizer safety valves are removed as described in the response to **QUESTION** No.19.492 of RAI #669-5219.
For the discussion in the two RAI responses, the requirement of GL 88-17 has no impact on operability and condition for SG reflux cooling. In addition, assumption that pressurizer safety valves are removed to prevent the damage of SG nozzle dams caused by loss of RHR will be documented in Table 19.1-119.

Impact on DCD

Assumption regarding operator action for SG reflux cooling in Table 19.1-119 will be revised as follows:

Table 19.1-119 Key Insights and Assumptions (Sheet 14 of 23)

Key Insights and Assumptions	Dispositions
14. In the case of loss of decay heat removal functions from RHR, with RCS temperature – high or RCS water level – low, operators feed water to SGs by motor-driven EFW pump, ~~and~~ open ~~safety~~ main steam depressurization valve and close the pressurizer spray vent valve (if the valve is opened) in order to remove decay heat from RCS.	19.2.5 COL 19.3(6) COL 13.5(7)

Table 19.1-119 Key Insights and Assumptions (Sheet 17 of 23)

Key Insights and Assumptions	Dispositions
13. Administrative controls ensure the RCS water level, temperature and pressure indication are available during shutdown. 14. Pressurizer safety valves are removed to prevent the damage of SG nozzle dams caused by loss of RHR while SG nozzle dams and the reactor vessel head are placed.	19.2.5 COL 19.3(6) COL 13.5(7) 5.4.7.2.3.6

Impact on R-COLA and S-COLA.

There is no impact on R-COLA and S-COLA.

Impact on PRA

There is no impact on PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

02/17/2011

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Docket No.52-021

RAI NO.:	**NO. 681-5257 REVISION 2**
SRP SECTION:	**19 – Probabilistic Risk Assessment and Severe Accident Evaluation**
APPLICATION SECTION:	**19**
DATE OF RAI ISSUE:	**01/20/2011**

QUESTION NO. : 19-497
The staff has reviewed MHI's response to RAI 19.01-7 which discusses the seismic margins analysis for LPSD. Opening the pressurizer depressurization valve in conjunction with SI system operation will be needed for POSs where the RCS is closed. The need for opening the SDV will not affect the shutdown plant level HCLPF since the HCLPF of the pressurizer depressurization valve is .8g, but will add another dominant human error which should be documented in Section 19.1.6.3.1 of the DCD. The staff is requesting MHI to document this dominant human error for the LPSD seismic margins analysis in Section 19.1.6.3.1 of the DCD.

ANSWER:

The response to RAI 19.01-7 discussed focusing on SI system operation only. In this case, opening of the pressurizer safety valves (SDV) will be required to prevent RCS pressurization caused by make-up water during RCS closed states. Therefore, MHI will add a new sentence "(<u>The human error to open the SDV during the RCS closed states)</u>" in Section 19.1.6.3.1.

However, the decay heat removal by the SG reflux cooling is available prior to the SI system operation during the RCS closed states. The mixed cutsets for the min-max approach will involve the combination of failures of SI system and SG reflux cooling. Therefore, new sentences "<u>During the RCS closed states, decay heat removal by SG reflux cooling is also available prior to the SI system operation. The mixed cutsets are the combination of failures of SI system and failures of SG reflux cooling. The HCLPF of the SG is 0.67g, which is greater than 0.5g.</u>" will be added in Section 19.1.6.3.1.

<u>Impact on DCD</u>
The Following is a part of the DCD marked-up paragraphs of RAI 19.01-7 response. Underlined sentences will be added in the DCD Subsection 19.1.6.3.1.

As shown in Table 19.1-120, if the safety injection (SI) system is available, it does not result in core damage for all POSs and initiating events during LPSD.

The dominant seismic cutsets for the SI system are as follows:

No.	Seismic Cutsets (Description)	:HCLPF
1.	SE-EPSDLFFGTABCD (Emergency Gas Turbine Generators GTA, B, C, D)	: 0.50g
2.	SE-HPIPMFFSIPABCD (Safety Injection Pumps SIPA, B, C, D)	: 0.62g
3.	SE-EPSEPFFBCPABCD (Battery Charger Panels BCP-A, B, C, D)	: 0.75g
4.	SE-EPSEPFFIBDABCD (Instrument Power Distribution Panels IBD-A, B, C, D)	: 0.75g
5.	SE-EPSIVFFINVABCD Inverters INVA, B, C, D (Instrument Power Panels)	: 0.75g

Using the min-max method, the HCLPF for SI system is 0.50g.

Key random failures/human errors during LPSD are reviewed. For POS 8-1 and the initiating event LORH, only the SI system is expected to be functional after a seismic event, as noted in Figure 19.1-22.

Dominant random failures/human errors that lead to SI system failure are as follows:

No.	Dominant random failures/human errors (Description)	:Prob.
1.	HPIOO02S (Operators fail to start standby SI pumps)	:4.9E-3
2.	EPSCF3DLLRDG-ALL (GTG A,B,C fail to load and run after 1hr operation(CCF)*)	:1.1E-3
	(*: GTG-D is out of service during POS 8-1)	
	<u>(The human error for opening the SDV during the RCS closed states)</u>	

The dominant mixed cutsets are the combinations of seismic failures of non seismic category 1 SSCs and random failures/human errors.

Opening the pressurizer depressurization valve (SDV) in conjunction with SI system operation will be needed for POSs where the RCS is closed, such as POS 3. The need for opening the SDV will not affect the HCLPF sequence since the HCLPF of the SDV is 0.8g, which is greater than the HCLPF for the SI system. <u>Also during the RCS closed states, decay heat removal by SG reflux cooling is also available prior to the SI system operation. The practical mixed cutsets will be the combination of failures of SI system and failures of SG reflux cooling. The HCLPF of the SG is 067g, which is greater than 0.5g.</u>

SSCs for LPSD mitigation systems are involved in the list of SSCs for at-power SMA and the HCLPFs of the SSCs are not less than 0.5g.

<u>Impact on R-COLA and S-COLA.</u>
There is no impact on R-COLA and S-COLA.

<u>Impact on PRA</u>
There is no impact on PRA.

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RAI NO.:	**NO. 681-5257 REVISION 2**
SRP SECTION:	**19 – Probabilistic Risk Assessment and Severe Accident Evaluation**
APPLICATION SECTION:	**19**
DATE OF RAI ISSUE:	**01/20/2011**

QUESTION NO. : 19-498
For the success criteria assumed in the USAPWR LPSD PRA, the staff requests MHI to evaluate and discuss in the DCD whether containment cooling is necessary to prevent core damage and/or sustain RCS injection for all sequences that are assumed to end a successful endstate.

ANSWER:

The discussion that containment cooling is unnecessary to prevent core damage and/or to sustain RCS injection will be documented in Chapter 19. The basis is as follows:

Core damage defined in LPSD PRA is uncovery of reactor core. This implies that neither losses of RCS injection for RCS inventory make-up nor losses of decay heat removal directly lead to core damage, regardless of containment cooling. The definition is more conservative, when taking into consideration that decay heat level is lower than that in at-power operation. For long-term cooling, the containment cooling function has small impact on risk during LPSD operation because of a lower decay heat level and sufficiently longer allowable time for operator action before core uncovery. In addition, there is a possibility that containment fan cooler units will be operating as a containment cooling function. Therefore, containment cooling has no impact on prevention of core damage.

RCS injection systems considered in the LPSD are as follows:

- Charging injection
- Safety injection
- Gravity injection

(RHR operation and SG reflux cooling are decay heat removal function)

Operability of the RCS injection systems other than gravity injection is independent from the status of containment cooling. This is because these systems are designed to inject water to the RCS in accident during at-power operation, which is more severe condition (e.g., higher RCS pressure) than LPSD condition. For gravity injection, there will be a possibility that this function becomes inoperable caused by pressurization due to no containment cooling. However, considering the various uncertainties such as operation of containment fan units or state of airlock for containment, MHI judges that containment cooling has less impact on operability of gravity injection. In addition, if gravity injection is assumed to be unavailable due to RCS pressurization, the total CDF is approximately 7% higher than the base case CDF (1.8E-07/RY).

Impact on DCD
Page 19.1-113 of DCD Chapter 19 will be revised as follows:

~~In general, the success criteria for the LPSD PRA are the same as for the Level 1 internal events PRA at power (see Subsection 19.1.4.1.1).~~ Core damage for the LPSD PRA is defined as uncovery of reactor core. Either decay heat removal functions or RCS inventory make-up functions can prevent core damage, regardless of containment cooling.

The assumptions of success criteria specific to the LPSD PRA are as follows:

- For manual operation, one hour is conservatively assumed to be the allowable time until the exposure of reactor core from previous PRA studies and experience which mid-loop operation.
- When the RCS is under atmospheric pressure, it is assumed that the gravitational injection from SFP is effective. The gravitational injection from SFP is established by opening the injection flow path from SFP to RCS cold legs, and the water supply path from the RWSP to SFP. The validity of this function is determined by engineering judgment based on the previous PRA studies.
- When the RCS is in mid-loop operation, it is assumed that the reflux cooling with the SGs is effective. The validity of this function is determined by engineering judgment based on previous PRA studies.
- The containment cooling function is unnecessary to prevent core damage and to sustain RCS injection due to the allowable time until core uncovery and the lower decay heat level.

The success criteria of mitigation function are established based on engineering judge, taking into account the similar success criteria used in Level 1 PRA during at-power operation, the decay heat level, plant configuration and so on. As an example, the success criteria for each system during POS 8-1 are given in Table 19.1-85.

Impact on R-COLA and S-COLA.
There is no impact on R-COLA and S-COLA.

Impact on PRA
There is no impact on PRA.