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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-10124

Subject: MHI's Response to US-APWR DCD RAI No. 568-4588 Revision 1

References:
1) "Request for Additional Information 568-4588 Revision 1 SRP Section 7.05 – Information Systems Important to Safety, Application Section 7.5", dated April 13, 2010
2) MHI letter UAP-HF-09501, "MHI's Response to US-APWR DCD RAI No. 463-3746 Revision 0 and Open Item OI-SRP16-CTSB-1769/284", dated October 28, 2009

Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") the document entitled "MHI's Response to US-APWR DCD RAI No. 568-4588 Revision 1". Enclosure 1 provides MHI's response to Reference 1, which is considered supplemental information in support MHI's previous response (Reference 2) regarding US-APWR Post-Accident Monitoring Instrumentation.

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

Sincerely,

Y. Ogata

Yoshiki Ogata
General Manager- APWR Promoting Department
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Enclosures:

1. MHI's Response to US-APWR DCD RAI No. 568-4588 Revision 1 (non-proprietary)

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ENCLOSURE 1

UAP-HF-10124
Docket No. 52-021

MHI's Response to US-APWR DCD RAI No. 568-4588 Revision 1

April 2010

(Non-Proprietary)

4/28/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 568-4588 REVISION 1**
SRP SECTION:	**07.05 – INFORMATION SYSTEMS IMPORTANT TO SAFETY**
APPLICATION SECTION:	**07.05**
DATE OF RAI ISSUE:	**4/13/2010**

QUESTION NO.: 07.05-18

Provide a complete explanation of the differences between Table 7.5-3, Post Accident Monitoring System (PAMS) Variables, and all information in 1) Type A variables and those found in Table 3.3.3-1, of NUREG-1431 and 2) Types B through E variables and those found in Regulatory Guide 1.97 Rev. 3, Table 3. (This request was discussed in the public meeting with MHI and the NRC staff on March 16, 2010)

10 CFR Part 50, Appendix A, General Design Criteria (GDC) 13, requires, in part, that instrumentation be provided to monitor variables and systems over their anticipated ranges for accident conditions as appropriate to ensure adequate safety. GDC 64 requires, in part, means for monitoring the reactor containment atmosphere, spaces containing components to recirculate loss-of-coolant accident fluids, effluent discharge paths, and the plant environs for radioactivity that may be released as a result of postulated accidents. One bounding list of PAMS instruments are those identified in the standard technical specifications for operating reactors and the list of PAMS instruments in Regulatory Guide 1.97, Revision 3. As stated in RAI No. 463-3746, Question No. 16-299, Table 7.5-3 provides a list of PAMS variables that has been developed based on a combination of previous revisions of RG 1.97, Japanese domestic and US operation plant experience and EOPs, and known differences between the US-APWR and current operating PWRs. The staff noted that some instrumentation in the US-APWR bounding list were absent when compared to the PAMS instrument lists in the standard technical specifications and Regulatory Guide 1.97, Revision 3. Additionally, there was no basis mentioned for the absent instrumentation. Substantiate to the staff that the list of PAMS variables in Table 7.5-3 is indeed a bounding list and complete. Specifically, identify and explain the reason for the missing instrumentation as compared to Table 3.3.3-1 of NUREG-1431 and Table 3 of Regulatory Guide 1.97, Revision 3.

ANSWER:

As stated in the response to RAI No. 463-3746, Question 16-299, the US-APWR PAM list provided in DCD Table 7.5-3 was developed to be in compliance with the guidance of RG 1.97 Rev. 4 and IEEE 497-2002. MHI utilized a combination of previous versions of RG 1.97, Japanese domestic and US operational experience and emergency procedures, and known differences between current operating plants and the US-APWR design to develop a bounding and complete PAM list for the US-APWR. The following sections describe the selection basis for the Type A, B, C, D, and E variables for the US-APWR.

- **Type A**

NUREG-1431 Table 3.3.3-1 provides a generic list of PAM instrumentation for a Westinghouse NSSS plant based on the guidance in RG 1.97 Rev. 3; however, a reviewer's note in NUREG-1431 requires that this table be amended by individual licensees to add all RG 1.97 Type A and Category 1 non-Type A variables to this generic list in accordance with the plant's RG 1.97 Safety Evaluation Report. Therefore the PAM list provided in NUREG-1431 is a minimal list of Category 1 variables (any Type) for a typical Westinghouse NSSS plant.

MHI utilized the performance-based criteria of RG 1.97 Rev. 4 and IEEE 497-2002 to select the Type A accident monitoring variables for the US-APWR. IEEE 497-2002 defines Type A variables as follows.

Type A variables are those variables that provide the primary information required to permit the control room operating staff to:

a) Take specific planned manually-controlled actions for which no automatic control is provided and that are required for safety systems to perform their safety-related functions as assumed in the plant Accident Analysis Licensing Basis.
b) Take specific planned manually-controlled actions for which no automatic control is provided and that are required to mitigate the consequences of an AOO.

As described in the response to RAI No. 07.05-9 in MHI letter UAP-HF-09196 dated April 28, 2009, the SGTR is the only event that assumes planned operator actions using the Type A variables listed in DCD Table 7.5-3. Planned operator actions required for other events are initiated by an alarm or they are based on a time limit.

In the event of an SGTR, the DBA analysis assumes the following specific operator actions:

- Identify and Isolate Ruptured SG
- Cool Down Primary Coolant System
- Depressurize Primary Coolant System to Equalize Pressure between Primary and Secondary
- Terminate Safety Injection Flow

Some Type A variables are monitored before the operator takes the above manual actions. These Type A variables are shown in Table A.

Regarding the LOCA event, RWSP level is an important indication in some currently operating plants because operator action is needed to realign the injection of ECCS from the RWSP to the containment sump before the RWSP becomes empty. In the US-APWR, the RWSP is located at the bottom of the containment and the suction of both the SIP and CS/RHRP is the RWSP from the beginning. Therefore, it is not necessary to confirm the RWSP level during the LOCA event and this variable is not included as a Type A variable for the US-APWR.

The analyses of the Steam Line Break (SLB) and Feedwater Line Break (FLB) assume EFW isolation from a faulted SG. However, this action is performed automatically by the low steam line pressure signal EFW isolation function. Therefore, there are no PAM instruments related to operator actions assumed in the SLB and FLB analyses.

In all DBA analysis, except for the SGTR previously discussed, explicit operator actions are not assumed based on primary information from PAM instruments. However, SI termination and long-term core cooling from secondary heat sink are necessary to bring the plant to cold shut down conditions. Operator actions for SI termination and core cooling are already included in the operator actions assumed in the SGTR analysis. Therefore, the instruments associated with these functions have already been included in the bounding PAM list provided in DCD Table 7.5-3.

Table A compares all of the Category 1 variables (any Type) functions in NUREG-1431 Table 3.3.3-1 to the US-APWR Type A variables listed in DCD Table 7.5-3 and summarizes the bases for differences between the Type A variables in the MHI PAM list and the Category 1 PAM for a typical Westinghouse 4-loop PWR plant.

- **Type B**

Table 3 of RG 1.97 Rev. 3 prescribes a minimum list of Type B variables to monitor. However, MHI utilized the performance-based criteria of RG 1.97 Rev. 4 and IEEE 497-2002 to select the Type B accident monitoring variables for the US-APWR. Therefore, there are some differences between the RG 1.97 Rev. 3 and MHI Type B variable lists. IEEE 497-2002 defines Type B variables as follows.

> Type B variables are those variables that provide primary information to the control room operators to assess the plant critical safety functions. Any plant critical safety functions addressed in the EPGs or the plant specific EOPs that are in addition to those identified above shall also be in included.

The ultimate goal of the plant safety systems is to prevent an uncontrolled release of radioactive material. This is accomplished by ensuring that certain parameters related to plant critical safety functions are not exceeded. The US-APWR Functional Restoration Guidelines (FRGs) provide protection of these plant critical safety functions. The FRGs establish predefined function-related restoration strategies for responding to emergency transients where the initiating event is unknown and the transient is not predefined. The restoration strategies utilize available plant equipment to restore the parameters used for entry conditions to values sufficient to ensure protection of the plant critical safety function.

The most essential and important methods of protecting the plant critical safety functions are the concepts of (1) Shutdown, (2) Cooldown, and (3) Contain, where each of these concepts is defined as follows.

- "Shutdown" means that the plant should be subcritical in order to reduce the thermal energy in the core to as low as the decay heat level during the emergency conditions.
- "Cooldown" means that the heat should be removed from the core (fuel rods) to protect the integrity of the cladding. Decay heat should be removed from the Reactor Coolant System (RCS).
- "Contain" refers to the integrity of the RCS and containment vessel. Heat should be removed from the containment to the ultimate heat sink.

The US-APWR Type-B PAM variables are selected from the concept of the FRGs described above. The Type B functional category of "Reactivity Control" is related to the FRG concept of "Shutdown". The functional categories of "Core Cooling" and "Reactor Coolant System Integrity" are related to the FRG concept of "Cooldown". And the Type B functional category "Containment Integrity" is related to the FRG concept "Contain".

Table B describes the bases for the differences between the Type B variables included in the MHI PAM list compared to those included in RG 1.97 Rev. 3 Table 3.

- **Type C**

Table 3 of RG 1.97 Rev. 3 prescribes a minimum list of Type C variables to monitor. However, MHI utilized the performance-based criteria of RG 1.97 Rev. 4 and IEEE 497-2002 to select the Type C accident monitoring variables for the US-APWR. Therefore, there are some differences between the RG 1.97 Rev. 3 and MHI Type C variable lists. IEEE 497-2002 defines Type C variables as follows.

> Type C variables are those variables that provide primary information to the control room operators to indicate the potential for breach or the actual breach of the three fission product barriers (extended range): fuel cladding, reactor coolant system pressure boundary, and containment pressure boundary.

Table C shows the bases for the differences between Type C variables in the MHI PAM list and the variables included in RG 1.97 Rev. 3 Table 3.

- **Type D**

Table 3 of RG 1.97 Rev. 3 prescribes a minimum list of Type D variables to monitor. However, MHI utilized the performance-based criteria of RG 1.97 Rev. 4 and IEEE 497-2002 to select the Type D accident monitoring variables for the US-APWR. Therefore, there are some differences between the RG 1.97 Rev. 3 and MHI Type D variable lists. IEEE 497-2002 defines Type D variables as follows.

> Type D variables are those variables that provide primary information to the control room

operators and are required in procedures and LBD to:

a) Indicate the performance of those safety systems and auxiliary supporting features necessary for the mitigation of design basis events.
b) Indicate the performance of other systems necessary to achieve and maintain a safe shutdown condition.
c) Verify safety system status.

The US-APWR Type D variable list is almost identical to the Type D variables included in Table 3 of RG 1.97 Rev.3. One notable departure is the variable to monitor flow in the low pressure injection system. The accumulators and high head safety injection system in US-APWR are designed to replace the entire low head safety injection function; therefore, this system is not part of the US-APWR design and this monitoring variable is not applicable to the US-APWR.

Another notable departure from the RG 1.97 Rev.3 Type D variable list involves the chemical volume and control system (CVCS). The high head injection system and emergency letdown system of the US-APWR has a required safety function to ensure a means for feed and bleed for boration and make up water for compensation of shrinkage if the normal CVCS is unavailable. Since the US-APWR SI system performs the necessary RCS inventory and boration functions, the CVCS-related monitoring variables are not necessary for the US-APWR design and thus not included in the MHI Type D variable list.

Table D shows the bases for differences between Type D variables in the MHI PAM list and Type D PAM included in RG 1.97 Rev. 3 Table 3.

• **Type E**

Table 3 of RG 1.97 Rev. 3 prescribes a minimum list of Type E variables to monitor. However, MHI utilized the performance-based criteria of RG 1.97 Rev. 4 and IEEE 497-2002 to select the Type E accident monitoring variables for the US-APWR. Therefore, these are some differences between the RG 1.97 Rev. 3 and MHI Type E variable lists. IEEE 497-2002 defines Type E variables as follows.

> Type E variables are those variables that provide primary information to the control room operators and are required for use in determining the magnitude of the release of radioactive materials and continually assessing such releases.
>
> The selection of these variables shall include, but not be limited to, the following:
>
> a) Monitor the magnitude of releases of radioactive materials through identified pathways (e.g., secondary safety valves, and condenser air ejector).
> b) Monitor the environmental conditions used to determine the impact of releases of radioactive materials through identified pathways (e.g., wind speed, wind direction, and air temperature).
> c) Monitor radiation levels and radioactivity in the plant environs.
> d) Monitor radiation levels and radioactivity in the control room and selected plant areas where access may be required for plant recovery.

Table E shows the bases for differences between Type E variables in the MHI PAM list and Type E PAM included in RG 1.97 Rev. 3 Table 3.

Impact on DCD

There are typographical mistakes in the Tier 2, DCD Chapter 7, Table 7.5-3. DCD Table 7.5-3 will be revised as shown below to add an additional category to Reactor Coolant Pressure, Containment Pressure, and Containment High Range Area Radiation.

Table 7.5-3 PAM Variables
(Sheet 1 of 3)

Variable	**Range**	**Monitored Function or System**	**Quantity**	**Type**
Reactor Coolant Pressure	0 to 3000 psig	Core Cooling Maintaining RCS Integrity	2	A,B, C,D
Containment Pressure[*2]	-7 to 80 psig	Maintaining RCS Integrity Maintaining Containment Integrity	4	B,C, D

Table 7.5-3 PAM Variables
(Sheet 2 of 3)

Variable	**Range**	**Monitored Function or System**	**Quantity**	**Type**
Containment High Range Area Radiation[*2]	1 to 1E-7 R/hr	Containment Radiation	4	C,E

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

Table A: Basis for Differences between NUREG-1431 Table 3.3.3-1 and the MHI Type A PAM List

RG 1.97 Function	Purpose	NUREG-1431 Table 3.3.3-1 Variable	Corresponding MHI Type A PAM Variable	Basis for Difference
Reactivity Control	Indication of subcritical conditions	Power Range Neutron Flux	-	This parameter is not applied in the safety analysis. Wide Range Neutron Flux is a Type B and D variable for the US-APWR.
Reactivity Control	Indication of subcritical conditions	Source Range Neutron Flux	-	This parameter is not applied in the safety analysis.
Core Cooling	Indication of core cooling; Manual action; Long-term core cooling	RCS Hot Leg Temperature	Reactor Coolant Hot Leg Temperature (Wide Range)	Intact loop hot leg temperature is applied for determining the termination of RCS cooldown and initiation of RCS depressurization in the SGTR analysis. Therefore, this is a Type A variable for the US-APWR.
Core Cooling	Indication of core cooling; Long-term core cooling	RCS Cold Leg Temperature	Reactor Coolant Cold Leg Temperature (Wide Range)	This parameter is not explicitly assumed in safety analysis; however, monitoring of this parameter is necessary for cooling down after mitigating a PA or AOO. Therefore, this is a Type A parameter for the US-APWR.
Core Cooling; Maintaining RCS Integrity; RCS Pressure Boundary; Primary Coolant System	-SGTR Safety Analysis Manual Action -RCS Depressurization based on EOPs for SGTR event	RCS Pressure (Wide Range)	Reactor Coolant Pressure	No difference.
Core Cooling	To ensure RCS inventory	Reactor Vessel Water Level	-	This parameter is not applied in the safety analysis. RV Water Level is a Type B and D variable for the US-APWR.
Core cooling; Maintaining RCS Integrity; RCS Pressure Boundary	Indication of core cooling function for RWSP switchover and status of ECCS recirculation delivery	Containment Sump Water Level (Wide Range)	-	This parameter is not applied in safety analysis since the US-APWR RWSP is located inside containment and does not require switchover to the recirculation sump. RWSP level is a Type B and D variable for the US-APWR.
Maintaining Containment and RCS Integrity; RCS Pressure Boundary	Indication of containment integrity function	Containment Pressure	-	This parameter is not applied in the safety analysis. Containment Pressure is a Type B and D variable for the US-APWR.

Table A: Basis for Differences between NUREG-1431 Table 3.3.3-1 and the MHI Type A PAM List

RG 1.97 Function	Purpose	NUREG-1431 Table 3.3.3-1 Variable	Corresponding MHI Type A PAM Variable	Basis for Difference
Containment Isolation/Integrity	Indication of containment integrity function	Penetration Flow Path Containment Isolation Valve Position	-	This parameter is not applied in the safety analysis. C/V Isolation Valve Position is a Type B and D variable for the US-APWR.
Containment Radiation; RCS Pressure Boundary	Identify challenge to fission product barrier	Containment Area Radiation (High Range)	-	This parameter is not applied in the safety analysis. Containment Area Radiation is a Type C and E variable for the US-APWR.
Primary Coolant System; RCS Pressure Boundary	To ensure proper operation of the pressurizer	Pressurizer Level	Pressurizer Water Level	No difference. This is a Type A variable for the US-APWR.
Secondary System; RCS Pressure Boundary	Verification of heat sink availability	Steam Generator Water Level (Wide Range)	-	This parameter is not applied in the safety analysis. SG narrow range level is applied in safety analysis and US-APWR ERG instead of this parameter. SG Wide Range Level is a Type B and D variable for the US-APWR.
Auxiliary Feedwater System	Indication of ability to maintain SG heat sink and indication of long-term AFW operation	Condensate Storage Tank Level	-	The EFW pit has enough water to maintain long-term core cooling; therefore, this variable is not applied in the safety analysis. This is a Type B and D variable for the US-APWR.
Core Cooling; Fuel Cladding Integrity; Maintain RCS Integrity; RCS Pressure Boundary; Primary Coolant System	Indication of core cooling	Core Exit Temperature – Quadrant [1]-[4]	-	This parameter is not applied in the safety analysis. Core Exit Temperature is a Type B and C variable for the US-APWR.
Auxiliary Feedwater System	Verification of automatic actuation and ability to satisfy heat sink requirements	Auxiliary Feedwater Flow	EFW Flow	No difference. This parameter is used to determine if the ECCS termination criteria are met in the SGTR analysis. EFW Flow is a Type A parameter for the US-APWR.
Secondary System	Verification of manual action for SGTR termination (along w/ RCS Pressure)	-	Main Steam Line Pressure	This parameter is applied for determining the termination of RCS cooldown and initiation of RCS depressurization in the SGTR analysis. Therefore, this is a Type A variable for the US-APWR.

Table A: Basis for Differences between NUREG-1431 Table 3.3.3-1 and the MHI Type A PAM List

RG 1.97 Function	Purpose	NUREG-1431 Table 3.3.3-1 Variable	Corresponding MHI Type A PAM Variable	Basis for Difference
Secondary System; RCS Pressure Boundary	Verification of heat sink availability	-	SG Water Level (Narrow Range)	This parameter is monitored for the operator to determine if the ECCS termination criteria are met in the SGTR analysis. This parameter is also used in the ERGs to identify ruptured SG(s). Therefore, this is a Type A variable for the US-APWR.
Core Cooling	Indication of core cooling	-	Degrees of Subcooling	This parameter is monitored for the operator to determine if the terminating RCS depressurization criteria or ECCS termination criteria are met in the SGTR analysis. Therefore, this is a Type A variable for the US-APWR.

Table B: Basis for Type B Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Reactivity Control			
Neutron Flux	Function detection; accomplishment of mitigation	Wide Range Neutron Flux	No difference
Control Rod Position	Verification	-	Reactivity control is directly monitored by Neutron Flux. Control rod position provides back-up indication of reactor shutdown. Since the primary indication is neutron flux, which is a PAM variable, control rod indication is not included in the US-APWR PAM list.
RCS Soluble Boron Concentration	Verification	Reactor Coolant Soluble Boron Concentration	No difference
RCS Cold Leg Water Temperature	Verification	Reactor Coolant Cold Leg Temperature (Wide Range)	No difference
Core Cooling			
RCS Hot Leg Water Temperature	Function detection; accomplishment of mitigation; verification; long-term surveillance	Reactor Coolant Hot Leg Temperature (Wide Range)	No difference
RCS Cold Leg Water Temperature	Function detection; accomplishment of mitigation; verification; long-term surveillance	Reactor Coolant Cold Leg Temperature (Wide Range)	No difference
RCS Pressure	Function detection; accomplishment of mitigation; verification; long-term surveillance	Reactor Coolant Pressure	No difference
Core Exit Temperature	Verification	Core Exit Temperature	No difference
Coolant Inventory	Verification; accomplishment of mitigation	RV Water Level	Reactor vessel water level is a key indication of adequate inventory for core cooling. There is no difference in the intent of these two variables.

Table B: Basis for Type B Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Degrees of Subcooling	Verification and analysis of plant conditions	Degrees of Subcooling	No difference
Maintaining Reactor Coolant System Integrity			
RCS Pressure	Function detection; accomplishment of mitigation	Reactor Coolant Pressure	No difference
Containment Sump Water Level	Function detection; accomplishment of mitigation; verification	Refueling Water Storage Pit Water Level (Wide Range) Refueling Water Storage Pit Water Level (Narrow Range)	The US-APWR RWSP is located inside containment, essentially combining the function of the sump and RWSP. Therefore, RWSP water level meets the intent of this monitoring variable and there is no difference between RG 1.97 Rev 3 and the US-APWR PAM list.
Containment Pressure	Function detection; accomplishment of mitigation; verification	Containment Pressure	No difference
Maintaining Containment Integrity			
Containment Isolation Valve Position (excluding check valves)	Accomplishment of isolation	Containment Isolation Valve Position (Excluding Check Valves)	No difference
Containment Pressure	Function detection; accomplishment of mitigation; verification	Containment Pressure	No difference
Other			
-	-	Pressurizer Water Level	This parameter is important to monitor because it is related to the SI termination criteria, which is related to maintaining adequate RCS inventory to assure core cooling.
-	-	Main Steam Line Pressure	This parameter is important to monitor the efficiency of removing the decay heat of core, which is related to core cooling.
-	-	SG Water Level (Wide Range)	This parameter provides indication of heat sink availability and is selected to monitor core cooling.
-	-	SG Water Level (Narrow Range)	This parameter provides indication of heat sink availability and is selected to monitor core cooling.

Table B: Basis for Type B Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
-	-	EFW Flow	This parameter provides verification of the automatic actuation of EFW and is selected to monitor core cooling.
-	-	EFW Pit Water Level	This parameter provides indication of heat sink availability and is selected to monitor core cooling.

Table C: Basis for Type C Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Fuel Cladding			
Radioactivity Concentration or Radiation Level in Circulating Primary Coolant	Detection of breach	Radioactivity Concentration or Radiation Level in Circulating Primary Coolant	No difference
Core Exit Temperature	Detection of breach	Core Exit Temperature	No difference
Analysis of Primary Coolant (Gamma Spectrum)	Detail analysis; accomplishment of mitigation; verification; long-term surveillance	-	Concentration of each radioactive nuclide can be derived from RCS sampling.
Reactor Coolant Pressure Boundary			
RCS Pressure	Detection of potential for or actual breach; accomplishment of mitigation; long-term surveillance	Reactor Coolant Pressure	No difference
Containment Pressure	Detection of breach; accomplishment of mitigation; long-term surveillance	Containment Pressure	No difference
Containment Sump Water Level	Detection of breach; accomplishment of mitigation; long-term surveillance	-	Containment Pressure is a more direct indication of a potential containment breach. Therefore, RWSP level is not included as a Type C variable for the US-APWR.
Containment Area Radiation	Detection of breach; verification	Containment High Range Area Radiation	No difference.
Effluent Radioactivity - Noble Gas Effluent from Condenser Air Removal System Exhaust	Detection of breach; verification	-	Coolant leakage outside containment to secondary system due to an actual breach of the reactor coolant pressure boundary can be detected by RCS pressure, SG water level, and pressurizer water level. These variables are PAM variables. Therefore, it is not necessary to include effluent radioactivity as a Type C variable.

Table C: Basis for Type C Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Containment			
RCS Pressure	Detection of potential for breach; accomplishment of mitigation	Reactor Coolant Pressure	No difference
Containment Hydrogen Concentration	Detection of potential for breach; accomplishment of mitigation; long-term surveillance	-	This instrumentation is used for monitoring severe accidents. Therefore, it does not need to be a Type C variable.
Containment Pressure	Detection of potential for or actual breach; accomplishment of mitigation	Containment Pressure	No difference
Containment Effluent Radioactivity - Noble Gas Effluent from Identified Release Points	Detection of breach; accomplishment of mitigation; verification	-	The plant vent receives the discharge from the containment purge, auxiliary building, control building, fuel building, and the condenser air removal filtration system. This variable can be measured by plant vent radiation monitor (including high range) and therefore is not included as a separate Type C variable for the US-APWR.
Effluent Radioactivity - Noble Gases (from buildings or areas where penetrations and hatches are located, e.g., secondary containment and auxiliary buildings and fuel handling buildings that are in direct contact with primary containment)	Indication of breach	-	The plant vent receives the discharge from the containment purge, auxiliary building, control building, fuel building, and the condenser air removal filtration system. This variable can be measured by plant vent radiation monitor (including high range) and therefore is not included as a separate Type C variable for the US-APWR.

Table D: Basis for Type D Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Residual Heat Removal (RHR) or Decay Heat Removal System			
RHR System Flow	To monitor operation	CS/RHR Pump Discharge Flow CS/RHR Pump Minimum Flow	No difference
RHR Heat Exchanger Outlet Temperature	To monitor operation and for analysis	-	Proper operation of the RHR system is verified by CS/RHR flow rate. Additionally, T_{hot} and T_{cold} are available to monitor RHR system performance with respect to decay heat removal. Therefore, it is not necessary to include the RHR heat exchanger outlet temperature as a Type D variable in the US-APWR PAM list.
Safety Injection System			
Accumulator Tank Level and Pressure	To monitor operation	Accumulator Water Level, Accumulator Pressure	No difference
Accumulator Isolation Valve Position	Operation status	-	Accumulator water level and accumulator pressure are available to monitor operation status. Therefore, it is not necessary to include isolation valve position as a separate Type D variable in the US-APWR PAM list.
Boric Acid Charging Flow	To monitor operation	-	The safety injection system delivers boric acid water to the RCS in the US-APWR. Safety Injection Pump Discharge Flow and Safety Injection Pump Minimum Flow are available to monitor the flow. Therefore it is not necessary to include this as a Type D variable in the US-APWR PAM list.
Flow in HPI System	To monitor operation	Safety Injection Pump Discharge Flow Safety Injection Pump Minimum Flow	No difference
Flow in LPI System	To monitor operation	-	The US-APWR design allows the accumulators and high head safety injection system to fully replace the safety function associated with the low head safety injection system. Therefore, the MHI PAM list does not need any variables to indicate LPI system performance.

Table D: Basis for Type D Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Refueling Water Storage Tank Level	To monitor operation	Refueling Water Storage Pit Water Level (Wide Range) Refueling Water Storage Pit Water Level (Narrow Range)	No difference
Primary Coolant System			
Reactor Coolant Pump Status	To monitor operation	-	The safety analysis does not rely on the RCP to mitigate design basis events. The RCPs are also not necessary to achieve and maintain a safe shutdown condition. CCW header pressure is available to monitor CCW performance related to its function to deliver seal flow to the RCP in order to maintain its RCS pressure boundary function. Therefore, RCP status is not included as a PAM variable for the US-APWR.
Primary System Safety Relief Valve Positions (including PORV and code valves) or Flow Through or Pressure in Relief Valve Lines	Operation status; to monitor for loss of coolant	-	RCS pressure, Reactor Coolant Hot Leg Temperature, and Reactor Coolant Cold Leg Temperature are available to monitor operation status of the primary coolant system. Consistent trends in changes to the values of these variables are indicative of a loss of coolant. Therefore, it is not necessary to include position indication or flow indication for the primary relief valves in the PAM list.
Pressurizer Level	To ensure proper operation of pressure	Pressurizer Water Level	No difference
Pressurizer Heater Status	To determine operating status	-	Pressurizer water level and RCS pressure are indicative of the performance of the pressurizer heater. Therefore it is not necessary to separately include heater status in the PAM list.
Quench Tank Level	To monitor operation	-	This component is not necessary to mitigate design basis events, and not necessary to achieve and maintain a safe shutdown condition. Therefore, it is not included in the US-APWR PAM list.
Quench Tank Temperature	To monitor operation	-	Same as above
Quench Tank Pressure	To monitor operation	-	Same as above

Table D: Basis for Type D Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Secondary System (Steam Generator)			
Steam Generator Level	To monitor operation	SG Water Level (Wide Range), SG Water Level (Narrow Range)	No difference
Steam Generator Pressure	To monitor operation	Main Steam Line Pressure	No difference
Safety/Relief Valve Positions or Main Steam Flow	To monitor operation	-	Main steam line pressure is indicative of main steam flow and is available to monitor its SG operation. Therefore it is not necessary to separately include this variable in the PAM list.
Main Feedwater Flow	To monitor operation	-	SG water level and main steam line pressure are indicative of adequate feedwater flow. Since these variables are available to monitor SG operation, it is not necessary to separately include MFW flow in the PAM list.
Auxiliary Feedwater or Emergency Feedwater System			
Auxiliary or Emergency Feedwater Flow	To monitor operation	EFW Flow	No difference
Condensate Storage Tank Water Level	To ensure water supply for auxiliary feedwater	EFW Pit Water Level	No difference
Containment Cooling Systems			
Containment Spray Flow	To monitor operation	CS/RHR Pump Discharge Flow CS/RHR Pump Minimum Flow	No difference
Heat Removal by the Containment Fan Heat Removal System	To indicate accomplishment of cooling	-	The containment fan heat removal system is not credited in design basis events since containment spray is credited to maintain containment integrity. Therefore this variable is not included in the PAM list.
Containment Atmosphere Temperature	To monitor operation	Containment Temperature	No difference

Table D: Basis for Type D Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Containment Sump Water Temperature	To monitor operation	-	Containment pressure, containment temperature, and containment spray flow are utilized to monitor containment cooling system performance. Therefore it is not necessary to include this variable in the US-APWR PAM list.
Chemical and Volume Control System (CVCS)			
Makeup Flow - In	To monitor operation	-	Since RCS inventory and boration are achieved by the safety injection system in the US-APWR, the monitoring variables related to CVCS are not necessary PAM variables for the US-APWR design.
Letdown Flow - Out	To monitor operation	-	Same as above
Volume Control Tank Level	To monitor operation	-	Same as above
Cooling Water System (CCW)			
Component Cooling Water Temperature to ESF System	To monitor operation	-	CCW header pressure provides indication of the performance of the cooling water system. Therefore it is not necessary to separately include this variable in the PAM list.
Component Cooling Water Flow to ESF System	To monitor operation	-	Same as above
Radwaste Systems			
High-Level Radioactive Liquid Tank Level	To indicate storage volume	-	The US-APWR design precludes the need for this variable. This component is not necessary to mitigate design basis events and not necessary to achieve and maintain a safe shutdown condition. Addition of additional radioactive waste to the liquid or gaseous radwaste system following an accident is precluded by design and is not postulated. Therefore, this variable is not included in the US-APWR PAM list.
Radioactive Gas Holdup Tank Pressure	To indicate storage capacity	-	Same as above
Ventilation Systems			
Emergency Ventilation Damper Position	To indicate damper status	-	Containment Isolation Valve Position provides indication of containment integrity. The combination of isolation valve position status and a lack of radioactive release as indicated by the plant vent monitor provides verification of proper automatic ventilation path isolation. Therefore, damper position indication is not included in the US-APWR PAM list.

Table D: Basis for Type D Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Power Supplies			
Status of Standby Power and Other Energy Sources Important to Safety (electric, hydraulic, pneumatic) (voltages, currents, pressures)	To indicate system status	Status of Standby Power and Other Energy Sources Important to Safety Class 1E ac Bus Voltage Class 1E dc Bus Voltage	No difference
Other			
-	-	Reactor Coolant Hot Leg Temperature (Wide Range)	This variable indicates the performance of the primary coolant system for maintaining core cooling.
-	-	Reactor Coolant Cold Leg Temperature (Wide Range)	Same as above
-	-	Reactor Coolant Pressure	This variable indicates the performance of the primary coolant system for maintaining core cooling and RCS integrity.
-	-	Degrees of Subcooling	This variable is used to indicate the performance of the primary coolant system for core cooling.
-	-	RV Water Level	This variable provides direct indication of inventory available for maintaining core cooling.
-	-	Wide Range Neutron Flux	This variable directly indicates reactivity control and allows for the monitoring of the performance of the control rod assemblies.
-	-	Containment Pressure	This variable is used to indicate the containment integrity status.
-	-	Containment Isolation Valve Position (Excluding Check Valves)	This variable is used to indicate the containment integrity status.
-	-	CCW Header Pressure	This variable is used to indicate the performance of the CCW system.
-	-	ESW Header Pressure	This variable is used to indicate the performance of the ESW system.

Table E: Basis for Type E Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Containment Radiation			
Containment Area Radiation - High Range	Detection of significant releases; release assessment; long-term surveillance; emergency plan actuation	Containment High Range Area Radiation	No difference
Area Radiation			
Radiation Exposure Rate (inside buildings or areas where access is required to service equipment important to safety)	Detection of significant releases; release assessment; long-term surveillance	-	This parameter can be measured by area monitors located where personnel enter areas after the accident. Additional personnel protection will be provided by the use of portable radiation monitors and air sampling. Therefore, it is not necessary to include this variable in the US-APWR PAM list.
Airborne Radioactive Materials Released from Plant			
Noble Gases and Vent Flow Rate			
Containment or Purge Effluent	Detection of significant releases; release assessment	-	The plant vent receives the discharge from the containment purge, auxiliary building, control building, fuel building, and the condenser air removal filtration system. These variables can be measured by plant vent radiation monitor (including high range) and therefore are not included as separate Type E variables for the US-APWR.
Reactor Shield Building (if in design)	Detection of significant releases; release assessment	-	
Auxiliary Building (including any building containing primary system gases, e.g., waste gas decay tank)	Detection of significant releases; release assessment; long-term surveillance	-	
Condenser Air Removal System Exhaust	Detection of significant releases; release assessment	-	

Table E: Basis for Type E Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Common Plant Vent or Multipurpose Vent Discharging Any of Above Releases (if containment purge is included)	Detection of significant releases; release assessment; long-term surveillance	-	This variable can be measured by plant vent radiation monitor (including high range) and therefore is not included as a separate Type E variable for the US-APWR.
Vent From Steam Generator Safety Relief Valves or Atmospheric Dump Valves	Detection of significant releases; release assessment	-	This variable is measured by main steam line monitor. Therefore it is not included as a separate Type E variable for the US-APWR.
All Other Identified Release Points	Detection of significant releases; release assessment; long-term surveillance	-	This variable can be measured by plant vent radiation monitor (including high range) and therefore is not included as a separate Type E variable for the US-APWR.
Particulates and Halogens			
All Identified Plant Release Points (except steam generator safety relief valves or atmospheric steam dump valves and condenser air removal system exhaust). Sampling with Onsite Analysis Capability	Detection of significant releases; release assessment; long-term surveillance	-	This can be measured by plant vent sampler (accident sampler). Therefore it is not included as a separate Type E variable for the US-APWR.
Environs Radiation and Radioactivity			
Airborne Radiohalogens and Particulates (portable sampling with onsite analysis capability)	Release assessment; analysis	Airborne Radio Halogens and Particulates (Portable Sampling with Onsite Analysis Capability)	No difference
Plant and Environs Radiation (portable instrumentation)	Release assessment; analysis	Plant and Environs Radiation (Portable Instrumentation)	No difference

Table E: Basis for Type E Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Plant and Environs Radioactivity (portable instrumentation)	Release assessment; analysis	Plant and Environs Radioactivity (Portable Instrumentation)	No difference
Meteorology			
Wind Direction	Release assessment	Meteorological Parameters (Wind Direction, Wind Speed, Estimation of Atmospheric Stability)	No difference
Wind Speed	Release assessment	Meteorological Parameters (Wind Direction, Wind Speed, Estimation of Atmospheric Stability)	No difference
Estimation of Atmospheric Stability	Release assessment	Meteorological Parameters (Wind Direction, Wind Speed, Estimation of Atmospheric Stability)	No difference
Accident Sampling Capability (Analysis Capability On Site)			
Primary Coolant and Sump ・Gross Activity ・Gamma Spectrum ・Boron Content ・Chloride Content ・Dissolved Hydrogen or Total Gas ・Dissolved Oxygen ・pH	Release assessment; verification analysis	-	These parameters can be measured by sampling. Many operating plants have received NRC approval for eliminating the PASS requirements specified in RG 1.97 Rev. 3. Therefore, these parameters are also not included in the US-APWR Type E PAM list.

Table E: Basis for Type E Differences between RG 1.97 Rev.3 and the MHI PAM List

RG 1.97 Rev. 3 Variable	Purpose	MHI PAM Variable	Basis for Difference
Containment Air • Hydrogen Content • Oxygen Content • Gamma Spectrum	Release assessment; verification analysis	-	These parameters can be measured by sampling. Many operating plants have received NRC approval for eliminating the PASS requirements specified in RG 1.97 Rev. 3. Therefore, these parameters are also not included in the US-APWR Type E PAM list.
Other			
-	-	MCR Area Radiation	To monitor radiation and radioactivity levels in the control room.
-	-	MCR Outside Air Intake Radiation	To monitor radiation and radioactivity levels in the control room.
-	-	TSC Outside Air Intake Radiation	To monitor radiation and radioactivity levels in the technical support center.
-	-	Plant Vent Radiation Gas Radiation (Including High Range)	To monitor the magnitude of releases of radioactive materials through identified pathways.
-	-	Main Steam Line Radiation	To monitor the magnitude of releases of radioactive materials through identified pathways.
-	-	GSS Exhaust Fan Discharge Line Radiation (Including High Range)	To monitor the magnitude of releases of radioactive materials through identified pathways.
-	-	Condenser Vacuum Pump Exhaust Line Radiation (Including High Range)	To monitor the magnitude of releases of radioactive materials through identified pathways.
-	-	Plant Air Vent High Concentration Sampling System	To monitor the magnitude of releases of radioactive materials through identified pathways.