Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, D.C. 20555

Direct tel: 412-374-6206
Direct fax: 724-940-8505
e-mail: sisk1rb@westinghouse.com

Your ref: Docket No. 52-006
Our ref: DCP_NRC_002980

July 27, 2010

Subject: AP1000 Response to Proposed Open Item (Chapter 19)

Westinghouse is submitting the following responses to the NRC open item (OI) on Chapter 19. These proposed open item responses are submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in these responses is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following proposed Open Item(s):

OI-SRP19.0-SPLA-12 R3

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Proposed Open Item (Chapter 19)

D063
NRO

0605ljb.doc

cc:	D. Jaffe	-	U.S. NRC	1E
	E. McKenna	-	U.S. NRC	1E
	S. Sanders	-	U.S. NRC	1E
	T. Spink	-	TVA	1E
	P. Hastings	-	Duke Power	1E
	R. Kitchen	-	Progress Energy	1E
	A. Monroe	-	SCANA	1E
	P. Jacobs	-	Florida Power & Light	1E
	C. Pierce	-	Southern Company	1E
	E. Schmiech	-	Westinghouse	1E
	G. Zinke	-	NuStart/Entergy	1E
	R. Grumbir	-	NuStart	1E
	T. Ray	-	Westinghouse	1E

ENCLOSURE 1

AP1000 Response to Proposed Open Item (Chapter 19)

OI Response Number: OI-SRP19.0-SPLA-12
Revision: 3

Question:

In 10 CFR 52.47, "Contents of applications; technical information," there is a requirement that each application for design certification must include a "description of the design-specific probabilistic risk assessment (PRA) and its results" (§52.47(a)(27)).

Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)" includes Regulatory Position Part I, "Standard Format and Content of Combined License Applications." According to Section C.I.19.3 of this part, the scope of the assessment should be "a Level 1 and Level 2 PRA that includes internal and external events and addresses all plant operating modes."

Regulatory Guide 1.200," An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," endorses ASME RA-S–2008, "Standard for Probabilistic Risk Assessment for Nuclear Power Plant Applications" and ASME/ANS RA-Sa–2009, "Addenda to ASME/ANS RA-S–2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications."

Additional regulatory guidance is found in interim staff guidance: DC/COL-ISG-3, "PRA Information to Support Design Certification and Combined License Applications" (ISG-3) and DC/COL-ISG-020, "Seismic Margin Analysis for New Reactors Based on Probabilistic Risk Assessment" (ISG-20). ISG-20 identifies particular parts of the ASME/ANS standards that clarify the level of detail expected in the seismic margin analysis (SMA).

In support of design certification, the SMA is needed to confirm the adequacy of the seismic design and to identify plant-level seismic vulnerabilities. The staff's expectations for the SMA are detailed in ISG-20 as follows:

Topic	Applicable Interim Staff Guidance
1. plant system and accident sequence analysis	ISG-20, Section 5.1.1
2. seismic fragility evaluation	ISG-20, Section 5.1.2
3. plant-level capacity with HCLPF[1]	ISG-20, Section 5.1.3
4. assessment of capability	ISG-20, Section 5.1.3

In the application for amendment to the certified design, Westinghouse altered the specified site parameters. Two response spectra that were not considered in the certified design were added.

[1] When components that may control the plant-level capacity are qualified by prototype testing, the test response spectrum must be specified to demonstrate that no more than one percent rate of failure would be expected when the plant is subjected to the applicable seismic margin ground motion.

In addition, proposed design changes have removed SSCs that are identified in the Table 19.55-1, "Seismic Margin HCLPF Values." Design changes may have otherwise altered the makeup of the list or individual HCLPF values. The amended DCD should contain the applicant's basis for concluding that the original SMA is still applicable. It would be helpful if the amended DCD included a description of the updated SMA in addition to the summary of results. As in the case of other external events, identifying the important assumptions and results in the DCD will ensure that a COL applicant referencing the AP1000 design has the correct basis for confirming that the AP1000 SMA still applies when plant- and site-specific features are considered.

Revise Section 19.55 of the DCD to include a description of the SMA, including assumptions and methods, in addition to the summary of results. The DCD description must provide enough information for the staff to confirm that adequate seismic margin has been demonstrated or will be established for the amended design. ISG-20, Section 5.4, "Position on Documentation," provides a list of information that would be sufficient to allow the staff to confirm the acceptability of the SMA.

In addition, provide a COL information item requiring COL applicants to update the SMA to address plant- and site-specific features. The applicant should identify plant-specific vulnerabilities and confirm the basis of the SMA. If the plant-level HCLPF is less than the target value, the applicant should perform a full convolution of sequence fragility for all sequences with a potential to lead to core damage to demonstrate that the seismic risk is acceptably low for the licensed plant.

ISG-20 provides guidance on this process in Section 5.2, "Position on Updating DC PRA-Based Seismic Margin Analysis by COL Applicants."

Also revise COL Information Item 19.59.10-1, "As-Built SSC HCLPF Comparison to Seismic Margin Evaluation" to indicate that the test response spectra must be chosen so as to demonstrate that no more than one percent rate of failure would be expected when the plant is subjected to the applicable seismic margin ground motion. This is consistent with ISG-20, and clarifies how the COL holder may confirm that prototype testing has demonstrated adequate seismic margin on a plant- and site-specific basis.

Westinghouse Response:

Revision 3 of the Open Item response is a complete re-write of Revision 1 and 0. This also replaces the draft response Rev. 2 provided at the public meeting on April 26th and the response provided in OI-SRP19.0-SPLA-12-02 R2 (DCP_NRC_002739 issued January 14, 2010). Due to the extensive changes to Section 19.55 all of the changes have been accepted and this is provided as a complete re-write of 19.55. The only track change mark-ups being provided are for the additional words provided in COL action item 19.59.10.5.

The documentation of the AP1000 PRA-based SMA has been expanded to include a description of the seismic event trees that define the sequences that were analyzed. Updated HCLPF values have been factored into the analysis and the sequences and overall plant HCLPF values have been re-evaluated. This analysis demonstrates compliance with the requirements of SECY-93-087.

Design Control Document (DCD) Revision:

19.55 Seismic Margin Analysis

19.55.1 Introduction

In accordance with Section II.N, Site-Specific Probabilistic Risk Assessments (PRA) and Analysis of External Events, of SECY-93-087 (Reference 19.55-1), the U.S. Nuclear Regulatory Commission (NRC) approved the following staff recommendations:

> "PRA insights will be used to support a margins-type assessment of seismic events. A PRA-based seismic margin analysis will consider sequence-level High Confidence, Low Probability of Failures (HCLPFs) and fragilities for all sequences leading to core damage or containment failures up to approximately one and two-thirds the ground motion acceleration of the Design Basis SSE."

The PRA based seismic margin analysis (SMA) and the methodology described in this section is consistent with the recommendation of SECY-93-087.

Seismic margins methodology is employed to identify potential vulnerabilities and demonstrate seismic margin beyond the design-level safe shutdown earthquake (SSE). The capacity of those components required to bring the plant to a safe, stable condition is assessed. The structures, systems, and components identified as important to seismic risk are addressed. For this PRA-based seismic margin analysis, HCLPFs are calculated and reported at the sequence level. In addition, insights related to random and/or human failures are reported, as deemed appropriate, for each sequence.

19.55.2 Calculation of HCLPF Values

19.55.2.1 Seismic Margin HCLPF Methodology

The seismic margin analysis is based on established criteria, design specifications, existing qualification test reports, established basic design characteristics and configurations, and public domain generic data.

The seismic margin assessment is used to demonstrate margin over the SSE of 0.3g. Consistent with SECY-93-087 (Reference 19.55-1), the goal of the SMA is therefore to demonstrate that the plant HCLPF is at least 0.5g peak ground acceleration (pga). This is also called the review level earthquake (RLE). The AP1000 seismic response spectra are included in Chapter 5 (see Tier 2, Figures 5.0-1 through 5.0-4). It will be necessary for a COL (combined operating license) applicant to demonstrate that the seismic response for the applicant's plant is equal to or less than that used in the calculation of the HCLPF values, and to evaluate the potential for soil liquefaction using the applicant's site specific conditions. This will ensure a reserve margin that exceeds a 0.5g seismic level.

19.55.2.2 Calculation of HCLPF Values

A seismic margin analysis is made up of two major tasks:

1. A PRA-based model to determine the plant HCLPF
2. Determination of the plant structure and component HCLPFs

The second task, determination of HCLPF seismic acceleration values for plant structures and components, is discussed in this section; the PRA-based model is herein discussed as far as the seismic event trees and major assumptions associated with seismic fault trees development are concerned. The HCLPFs used in the analysis, which also include hard rock sites and extension to soil sites, are summarized in Table 19.55-1.

19.55.2.2.1 Review of Plant Information

The assessment uses the following plant information:

- Structural and seismic design criteria and procedures
- Structural design calculations
- Layout and design drawings
- Test reports
- Piping and instrumentation diagrams
- Equipment design specifications
- Generic fragility data
- AP1000 plant response spectra.

19.55.2.2.2 System Analysis

Section 7.4 of the AP1000 Design Control Document provides a discussion of the systems required for safe shutdown. The structures and components associated with these systems are considered in the seismic margin assessment. It is noted that the same success criteria as in the AP1000 PRA sensitivity case where no credit is taken for non-safety related systems, is used as the starting point for the AP1000 PRA-based seismic margins analysis. This success criterion is not necessarily defined in terms of reaching specific plant modes, but rather on reaching a sustainable safe plant state. The bases for these success criteria are given in the AP1000 PRA report (Reference 19.55-5).

19.55.2.2.3 Analysis of Structure Response

The purpose of a seismic fragility analysis is to define the maximum limit, seismic capacity, of functional capability or operability with the associated uncertainty for plant components and structures that could have an effect on safe shutdown of the plant following a seismic event. Capacity in the seismic margin assessment, expressed in terms of the free field peak ground level acceleration, is the level of the seismic event that results in failure of a given component or structure to perform its safety-related function. Failures leading to loss of safety function could result from such things as: loss of a pressure boundary; significant inelastic deformation; partial collapse; loss of support functions; or a combination of failure modes. In the calculation of the HCLPF value for a system, structure, or component, the governing failure mode is established by examining the different potential failure modes possible. Each failure mode has different reserve margin. As an example, ductility may be very large for tension failure, whereas, for buckling, ductility generally does not contribute to reserve margin.

A fragility evaluation is made for the key structures and components. The HCLPF for the equipment and structures is established using one of the following:

- Probabilistic fragility analysis
- Conservative deterministic failure margin (CDFM) method
- Test results
- Deterministic approach
- Generic fragility data

These methods are briefly discussed below.

Probabilistic Fragility Analysis

This method is used to define HCLPF values for structures such as:

- Steam generator supports
- Reactor pressure vessel supports
- Pressurizer supports
- Containment vessel

There are many sources of conservatism and variability in the estimation of seismic peak ground acceleration capacity for seismic margin assessment. HCLPF values reflective of the seismic capacity are derived from median capacity using formulas based on the log-normal distribution. The HCLPF values reflect a 95-percent confidence (probability) of not exceeding a 5-percent probability of failure (Reference 19.55-2).

The HCLPF is defined by a lognormal probability distribution that is a function of median seismic capacity and composite standard deviation, β_c:

$$\text{HCLPF} = \text{Median Capacity x } e^{[-2.3 \times \beta c]}$$

The median seismic capacity is related to the mean seismic capacity by the expression:

$$\text{Median Capacity} = \text{Mean Capacity x } e^{[-(\beta c^{\wedge}2)/2]}$$

The mean peak seismic ground capacity, A_m, is related to the stress and strength design margin factors by the following expression:

$$A_m = (\Pi_i [X_i])A_o$$

where

A_m	=	Mean peak seismic ground capacity
X_i	=	i^{th} design mean margin factor
Π_i	=	Product notation
A_o	=	Nominal seismic peak ground capacity

It is noted that the composite standard deviation is equal to the root mean square of the composite standard deviation associated with each of the margin factors. That is:

$$\beta_c = \sqrt{[\Sigma_i (\beta_c)_i^2]}$$

The conservatisms and variability identified and considered in this assessment are associated with stress and strength margin factors. The basic grouping of margin factors are: deterministic strength factor; variable strength factors; material; damping; inelastic energy absorption, ductility; and analysis or modeling error.

Conservative Deterministic Failure Margin Method

The HCLPF values for the shield building and the exterior walls of the Auxiliary Building were calculated using the conservative deterministic failure margin approach. A finite element analysis was performed of the structures that considered cracking of the concrete and redistribution of the loads. Deterministic margin factors were defined for three items: strength; inelastic energy absorption; and damping.

The polar crane HCLPF is calculated using the Westinghouse's design specification of Polar Crane and the vendor structural qualification calculation. The CDFM approach is used allowing the stress to reach yield and using a ductility factor of 1.25.

In addition, the HCLPF values for the Reactor Coolant Pump external heat exchanger and for the Passive Containment Cooling System are calculated with the CDFM approach.

Test Results

For the electrical equipment where documented test results are available, the HCLPF value is defined from comparison of required response spectra (RRS) and test response spectra (TRS). The method employed follows a deterministic approach using existing test data for similar types of equipment.

The existing test data was reviewed to determine a lower bound seismic capacity.

When the natural frequency of the equipment is not known, it was assumed that the natural frequency coincided with the required response spectra peak acceleration so that the lowest HCLPF value was calculated. It is noted that where equipment frequencies are known, and are used for comparing the RRS and TRS, these frequencies will be included in the design specification for the equipment to assure that the dynamic characteristics are the same as those expected.

Relay Chatter

Solid-state switching devices and electro-mechanical relays will be used in the AP1000 protection and control systems. Solid-state switching devices are inherently immune to mechanical switching discontinuities such as contact chatter. Robust electro-mechanical relays will be selected for AP1000 applications such that inherent mechanical contact chatter is within the required system performance criteria. Therefore, contact chatter has no effect on system operation and was, therefore, not included in the seismic margin analysis. The COL must confirm the use of seismically robust electro-mechanical relays in the engineered safety features actuation and control systems.

Moreover, the loss of offsite power event has a very low HCLPF value (0.09g). The control rod motor generator sets are powered by AC load centers that are de-energized on loss of offsite power sources. When the control rod motor generator sets are de-energized, current to the magnetic jack mechanisms stops and the gripper coils open, allowing the rods to drop into the core. Therefore, relay chatter is not an issue for reactor trip.

Finally, passive residual heat removal (PRHR) and core makeup tank (CMT) system valves automatically fail open upon loss of instrument air due to loss of seismically induced loss of offsite power. Thus, relay chatter is not an issue for PRHR and CMT system functions.

Deterministic Approach

A lower bound estimate of the HCLPF is obtained for selected structures or equipment based on margin to design limit for the appropriate load combination defined by the fault tree logic. Where applicable, the increased capacity due to inelastic energy absorption is defined using the recognized and recommended ductility factor of 1.25.

This approach was used for the primary components to verify that their supports would control the HCLPF value. It was also used for a few cases to define the HCLPF when it was apparent that its seismic capacity would not control the plant HCLPF value. This approach was used for: containment baffle plate supports; Interior Containemnt Structure and IRWST; PRHR heat exchanger; core makeup tank; and valves.

Generic Fragility Data

Generic fragility data was used when insufficient information was available to define the HCLPF value using one of the methods described above. Those cases where this approach was use were:

- Reactor internals and core assembly that includes fuel
- Control rod drive mechanism (CRDM)
- Reactor coolant pump

- Accumulator tank
- Piping
- Cable trays
- Valves
- Ceramic insulators

The Utility Requirements Document for Advanced Light Water Reactor, Reference 19.55-3, was used for all of the components listed above except ceramic insulators, which used recognized industry low seismic capacity data.

19.55.2.2.4 Evaluation of Seismic Capacities of Components and Plant

Table 19.55-1 provides the HCLPF values for the equipment, structures, and systems considered in the seismic margin evaluation. Also shown in this table is the approach used to define the HCLPF value, as described in subsection 19.55.2.2.3. The evaluation considers the effect of uplift and sliding of the nuclear island basemat foundation.

In the design of the AP1000, careful consideration is given to those areas that are recognized as important to plant seismic risk. In addition to paying special attention to those critical components that have HCLPF values close to the review level earthquake, the design process considers potential interaction with both safety-related and nonsafety-related systems or structures, as well as adequate anchorage load transfer and structural ductility. The seismic margin evaluation provides a means of identifying specific equipment and/or structures that are vulnerable to beyond design basis seismic events.

19.55.2.2.5 Verification of Equipment Fragility Data

The AP1000 safety-related equipment is designed to meet the safe shutdown earthquake requirements defined in Chapter 3 of the AP1000 DCD. This seismic margin evaluation has focused on demonstrating that the design of the nuclear island structures, safety-related equipment, and equipment supports can carry the loads induced by the review level earthquake discussed here. This evaluation incorporates as-specified equipment data. After the plant has been built, it will be necessary to perform a verification of the seismic margin assessment for the installed conditions.

19.55.2.2.6 Turbine Building Seismic Interaction

As part of the seismic margin assessment, the seismic interaction between the turbine building and the nuclear island was evaluated according to guidance provided in Reference 19.55-4. It was determined that:

- To protect the adjacent nuclear island auxiliary building the first bay of the turbine building has been classified as seismic category II.

- It is not likely that the size and energy of debris from the turbine building will be large enough to result in penetration through the auxiliary building roof structure.

Even though it is not likely that penetration of turbine building debris could be large enough or have sufficient energy for penetration through the auxiliary building roof structure, this event was evaluated. The consequences of damage to the safety-related equipment in the auxiliary building were investigated. It was determined from this investigation that should an event occur that causes the failure of equipment in the upper elevations of the auxiliary building, the results of the seismic margin assessment, the plant HCLPF value, and the insights derived from the seismic margin assessment are not affected. Moreover, the steam line break events, which would result from the damage of equipment in the upper elevations, are not dominant contributors to the core damage frequency. Further, the loss of equipment in the upper elevations will not affect the passive safety systems that would be used to put the plant in a safe shutdown condition should an event occur.

19.55.3 Seismic Margin Model

In this section, the AP1000 Risk-Based Seismic Margins Model is summarized and the plant HCLPF for AP1000 is determined.

HCLPFs are calculated for the seismic Category I safety-related systems that are called upon via the seismic event trees to mitigate an accident caused by the initiating seismic event.

19.55.3.1 Major SMA Model Assumptions

In this section, the general characteristics and major assumptions of the AP1000 SMA model are discussed.

1. The seismic event is assumed to occur while the plant is operating at full power.

2. A review level earthquake equal to 0.5g is used for the seismic margin analysis.

3. It is assumed that the seismic event would result in loss of offsite power, since the AC power equipment is not seismic Category I. (The offsite insulators on the feed lines from the offsite power grid fail such that a loss of offsite power occurs.) No credit is taken for onsite emergency AC power (diesel generators).

4. No credit is taken for non-safety related systems. They are assumed to have failed or be non-functional due to the seismic event. This includes all equipment in the turbine building and the turbine building itself; as discussed in Section 19.55.3.3, structural failure of the turbine building is assumed not to impact the structural integrity of the adjacent auxiliary building.

5. The seismically induced SMA initiating event categories and their event trees are taken from the AP600 PRA model. For each initiating event, the PRA logical modeling (i.e., seismic event and fault trees) developed for AP600 structures, systems, and components have been used as the starting point and their applicability to the AP1000 design has been assessed and confirmed. The applicability of the base AP600 to the AP1000 has been addressed in a supporting calculation. Cutsets

associated with each sequence are generated and then the min-max method is used to calculate the plant HCLPF value.

19.55.3.2 Seismic Initiating Events

The first step in Seismic Margins Model is to evaluate which initiating events could occur as a result of a seismic event. For this purpose, a Seismic Initiating Event Hierarchy Tree is constructed. This event tree is given in Figure 19.55-1 and discussed below. Based on this hierarchy event tree, seismic initiating event categories are defined and their event tree models are constructed (as discussed in subsection 19.55.3.3).

Given that a seismic event occurs, the hierarchy event tree is constructed such that the seismically-induced initiating event with the most challenge to the plant safety systems is considered first: gross structure collapse. This category is labeled as EQ-STRUC and is the first initiating event category to be modeled and quantified.

If gross structure collapse does not occur, next the reactor coolant system (RCS) loss-of-coolant-accident (LOCA) category in excess of emergency core cooling system (ECCS) capacity (also termed as "Vessel Failure") is considered. This category is labeled as EQ-RVFA.

If vessel failure does not occur, then large RCS LOCAs are considered. This category is labeled as EQ-LLOCA.

If EQ-LLOCA does not occur, then small RCS LOCAs are considered. This category is labeled as EQ-SLOCA. Steam generator tube rupture (SGTR) and large secondary line break (SLB) events are folded into the small LOCA category, as discussed in subsection 19.55.3.3.

Next considered is the seismically induced anticipated transient without scram (ATWS) event. This event is labeled as EQ-ATWS.

Finally, all other transients are considered in the category labeled EQ-LOSP. The seismically induced LOSP event occurs at low HCLPF values (e.g., lower than the SSE at 0.3g) and does not affect the plant HCLPF, as discussed in subsection 19.55.4.2. The cutsets for this event are all "mixed cutsets," containing seismically induced initiating event coupled with random failures leading to core damage. This event is included in the model for additional insights and completeness.

Thus, the hierarchy tree defines six initiating event categories. Each of these is discussed and an event tree for each is constructed in subsection 19.55.3.3.

The PRA-based seismic margins analysis does not consider seismic hazard curves. Therefore, initiating event frequencies are not calculated for each seismically generated initiating event category. Although seismically generated initiating event frequencies are not calculated, it is important to evaluate the seismic vulnerability of the components and systems that contribute to the initiating event categories. This is done by estimating a HCLPF for each seismic initiating event category, as discussed in subsection 19.55.3.3.

19.55.3.3 Seismic Event Trees

The six seismically induced initiating event categories defined by the hierarchy event tree model of subsection 19.55.3.2 are further discussed to model seismically induced failures that will determine the HCLPF for each of these initiating events. The six categories considered are:

1. EQ-STRUC — Gross structural collapse
2. EQ-RVFA — LOCA in excess of ECCS capacity
3. EQ-LLOCA — Large LOCA
4. EQ-SLOCA — Small LOCA
5. EQ-ATWS — ATWS
6. EQ-LOSP — Loss of offsite power

The small LOCA category also covers SGTR and SLB events. As discussed later in the success paths, the SLOCA success path used for SMA is also applicable (conservatively) to the SGTR and unisolated SLB events given that only safety-related systems are credited and considered in the PRA-based SMA. .

The last event, LOSP, is postulated at 0.09g. This event may also be viewed to represent a larger family of transients associated with loss of main feedwater, loss of compressed air, turbine trip, reactor trip, loss of service water/component cooling water, etc, following a seismic event and LOSP, since no credit is taken for these non-safety systems in the SMA models. Moreover, a seismically induced transient containing LOSP becomes a station blackout (SBO) event since no credit is taken for diesel generators which are not seismically qualified.

Each of the SMA events are further discussed below.

1. EQ-STRUC (Gross Structural Collapse)

   This event includes seismically induced failures of AP1000 structures that may result in core damage and large fission product release.

   The AP1000 structures are classified in 5 groups:

   1. Nuclear Island

      This consists of containment, shield building, and auxiliary building.

      Nuclear island is structurally designed to meet seismic Category I.

   2. Turbine Building

      The first bay of the turbine building is classified as Seismic Category II, and the remaining bays are designed to meet the uniform building code (UBC). For the SMA model, it is assumed to have failed. Thus no credit is taken for systems in this building.

3. Annex Building

   The high rise portion of the annex building is designed to meet seismic Category II. For the SMA model, it is assumed to have failed. Thus no credit is taken for systems in this building.

4. Diesel Generator Building

   The diesel generator building is designed to meet the UBC. For the SMA model, it is assumed to have failed. Thus no credit is taken for systems in this building.

5. Radwaste Building

   The radwaste building is designed to meet the UBC. For the SMA model, it is assumed to have failed. Thus no credit is taken for systems in this building.

Thus, only the nuclear island is considered for the SMA model; the interaction between the other buildings and the nuclear island is assumed to have no detrimental effect on the nuclear island structures. This assumption needs to be verified by a plant walkdown when an AP1000 plant is built.

The failures of the nuclear island structures are modeled in terms of the driving structures of the steel containment vessel, the shield building, and the auxiliary building.

The EQ-STRUC event tree is shown in Figure 19.55-2; HCLPF value for EQ-STRUC is calculated in Section 19.55.4.

2. EQ-RVFA (LOCA in Excess of ECCS Capacity)

This event represents the "vessel failures" where the event leads to excessive loss of RCS inventory that can not be made up by the ECCS capacity. In this case, core damage is postulated. A complete dependency between seismic induced failures of SSCs that share basic characteristics (i.e., component type, location/elevation, etc.), the "vessel failure" event comprises the following types of structural and component failures:

1. Seismically induced failures of the reactor vessel
2. Seismically induced failures of the steam generators
3. Seismically induced failures of the other RCS components
4. Seismically induced failures of two direct vessel injection (DVI) lines
5. Seismically induced failures of fuel.

The EQ-RVFA event tree is shown in Figure 19.55-3; HCLPF value for EQ-RVFA is calculated in Section 19.55.4.

3. EQ-LLOCA (Large LOCA)

Seismically induced large LOCA initiating event category, EQ-LLOCA, contains RCS breaks with break sizes greater than 9 inches. Since the seismic event failures assume that if one pipe breaks by a seismic event, all redundant similar pipes will break at the same time, all major RCS pipe breaks are conservatively included in this category; thus, no medium LOCA is defined in the initiating event hierarchy tree. Also included in this category are the failures of the passive RHR heat exchanger by a seismic event.

The EQ-LLOCA event tree is shown in Figure 19.55-4; HCLPF value for EQ-LLOCA is calculated in Section 19.55.4.

4. EQ-SLOCA (Small LOCA)

Seismically induced small LOCA initiating event category, EQ-SLOCA, contains RCS breaks with break sizes less than 2 inches of equivalent diameter. Since the seismic event failures assume that if one pipe breaks by a seismic event, all redundant similar pipes will break at the same time, all major RCS pipe breaks are conservatively included in the large LOCA category. For the small LOCA category, RCS leaks from instrument lines is used as the representative event. The small LOCA category also includes and bounds events such as

- Steam Generator Tube Rupture (SGTR)
- Large Steam Line Breaks (SLB) (due to generation of SI signal and RCS inventory shrinkage)

For SGTR events, breaks of one or more (up to 5) tubes have been considered for the AP1000 design. An event with 5 steam generator tubes rupturing has an equivalent LOCA break flow area of a 1.46 inch diameter hole. The rupture of more than 5 tubes by a seismic event is conservatively bounded by the structural failure of a steam generator, which is included in EQ-RVFA initiating event.

Due to the modification of the Reactor Coolant Pump (RCP) Heat Exchanger (HX) from the AP600 design to the AP1000 design, an additional entry is added to the seismic induced Small LOCA. This reflects the possibility that in the event of an RCP HX pipe break, a small LOCA will be induced. Flow from the RCS inventory will be restricted by the labyrinth seal surrounding the RCP motor shaft; tolerances on the labyrinth seal allow for a maximum flow area of $1.389 in^2$. This corresponds to approximately a 1.3 inch pipe break. A postulated seismic induced break of all eight tubes does not change the equivalent break flow rate for each pump and when considering the break in all pumps, a total of approximately 2.7 inch pipe break equivalent LOCA needs to be considered. This is judged to be consistent with the definition of seismically induced small LOCA given above.

The EQ-SLOCA event tree is shown in Figure 19.55-5; HCLPF value for EQ-SLOCA is calculated in Section 19.55.4.

5. EQ-ATWS (Anticipated Transients without Scram)

   The EQ-ATWS event addresses the seismically induced ATWS initiating event related to the failure of the core assembly or guide tubes or the control rod drive systems to remain functional so that the rods can not fall into the core. The fuel is still intact and can be cooled. The failure mode associated with seismically induced fuel failure has been already addressed in EQ-RVFA event.

   Because offsite power is postulated to have been lost, the control rod motor generator sets would be de-energized even if the reactor trip function failed. If the core assembly or the control rod system failed, the rods are postulated to fail to insert into the core.

   The EQ-ATWS event tree is shown in Figure 19.55-6; HCLPF value for EQ-ATWS is calculated in Section 19.55.4.

6. EQ-LOSP (Loss of Offsite Power)

   The EQ-LOSP event addresses the seismically induced loss of offsite power. This event occurs at relatively low intensity earthquakes. The driving failure for loss of offsite power is represented by failure of ceramic insulators in the switchyard. The HCLPF value for these insulators is 0.09g, which is lower than the review level earthquake of 0.5g, and the plant SSE of 0.3g. Such an earthquake does not challenge any of the safety-related systems that are built to withstand the SSE and have margin for higher g levels. Thus, this event does not lead to purely seismically driven failure combinations for a core damage sequence. This event model contains only "mixed cutsets" for core damage; these are failure combinations of seismically induced initiating event coupled with random failures of safety-related systems.

   The EQ-LOSP event tree is shown in Figure 19.55-7; this event does not contribute to plant HCLPF.

19.55.3.4 Seismic Fault Trees

System fault trees for mitigation functions have been modified to account for seismically-induced failures. The AP600 system seismic fault trees have been reviewed for applicability to the AP1000 and only limited and minor changes have been deemed necessary.

19.55.4 Calculation of Plant HCLPF

This section presents the seismic margin analysis calculations based on the model developed in subsection 19.55.3.

The initiating event HCLPFs are calculated in subsection 19.55.4.2. The plant HCLPF is calculated in subsection 19.55.4.3.

The analysis demonstrates that all structures and components required to maintain the plant in a safe stable state are expected to function following a seismic event of 0.5g acceleration.

19.55.4.1 HCLPFs for Basic Events

The HCLPF values for various AP1000 structures and components were determined in a supporting calculation and are given in Table 19.55-1. The basic events defined in the SMA model for seismic failures are assigned their own HCLPF values, as shown in Table 19.55-2. These HCLPF values are taken from Table 19.55-1. When not self evident, the "Source" column in Table 19.55-2 explains how the information Table 19.55-1 has been used.

For reasons beyond the development of the PRA-based AP1000 SMA, Table 19.55-1 groups all the electrical equipment into two major categories: *"Non-Sensitive to High Frequency Excitation"* and *"Sensitive to High Frequency Excitation"*. For the purposes of the PRA-based SMA, all electrical equipment has been assumed to be from the limiting categories among the two, which has an HCLPF value of 0.5; this assumption is for the purposes of this analysis only and is conservative for this purpose.

19.55.4.2 Calculation of Initiating Event HCLPFs

Initiating event HCLPFs are calculated by assigning the HCLPF values from Table 19.55-2 to the seismically induced failures modeled in subsection 55.3.3 for initiating events. The HCLPF associated to the Initiating Events will be the minimum among those for each of the potential initiator; the results of these calculations are given in Tables 19.55-3 through 19.55-7; results are presented for the AP1000 before and after this modification for DCD Rev.17. EQ-IEV-LOSP is already assigned a HCLPF 0.09g, representing the failure of ceramic insulators but it does not contribute to plant HCLPF since it has only mixed cutsets (seismic and random failures combined in cutsets).

The initiating event HCLPFs are summarized below:

Initiating Event	HCLPF	Dominated by
EQ-IEV-STRUC	0.55g	Polar crane
EQ-IEV-RVFA	0.50g	Fuel and pressurizer failure
EQ-IEV-LLOCA	0.81g	RCS piping
EQ-IEV-SLOCA	0.54g	Steam generator tube failure
EQ-IEV-ATWS	0.50g	Core assembly failures
EQ-IEV-LOSP	0.09g	Ceramic insulator failure

When the min-max method is used, the HCLPF of seismic sequences resulting from an initiating event can not be less than the initiating event HCLPF since it appears in every cutset. If the initiating event is postulated to directly lead to core damage, the IE HCLPF is used in the determination of the plant HCLPF.

Since both EQ-STRUC and EQ-RVFA events are postulated to lead to core damage, and EQ-STRUC is postulated to go to large early release as well, plant HCLPF can be determined at this point to be at least 0.50g for core damage and at least 0.55g for large, early release consequences.

19.55.4.3 Calculation of AP1000 Plant HCLPF

The final AP1000 plant HCLPF calculation also considers the mitigation portion of the PRA logic. Even though this is not going to change the values identified in section 19.55.4.2, the complete calculation provides further insights on the seismic margin of the AP1000 design.

All basic events in the AP1000 SMA model (listed in Table 19.55-2) are assigned a dummy probability value of 0.5; the model is then quantified and cutsets are generated. The min-max approach is then applied to the obtained cutsets at each failure sequence level to evaluate the sequence HCLPF value, the event tree HCLPF value and the overall plant HCLPF value.

The cutset generated from the SMA model are listed and analyzed through the min-max approach discussed above in a supporting calculation. Sequence level results are presented in Table 19.55-8 where also the plant level HCLPF value is presented.

19.55.5 Sensitivity Analyses

A 99% confidence associated with the test response spectra is expected for all the HCLPF extracted from tests (method [6] in Table 19.55-1). To address this expectation a sensitivity case was run to the AP1000 PRA-based SMA.

Since electrical equipment is tested and qualified to the SSE (i.e., 0.30g), the HCLPF values in Table 19.55-1 for all tested equipment are set to 0.3g. While the selected values are extremely conservative due to the engineering margins normally adopted for the qualification tests, such values would not change either the overall AP1000 plant HCLPF value or any sequence or event tree level HCLPF value.

19.55.6 Results and Insights

19.55.6.1 AP1000 SMA Results

The AP1000 PRA-based SMA has demonstrated that for structures, systems, and components required for safe shutdown the HCLPF magnitudes are equal to or greater than 0.50g. This HCLPF is determined by various structures, systems, and components with an HCLPF value of 0.5g.

Thus, the AP1000 plant can meet or exceed the requirement to withstand a review level earthquake of 0.5g. It is observed that electrical equipment qualification consistent with the Certified Seismic Design Response Spectra (CSDRS) at 0.3g (with a 99% confidence associated to the Test Response Spectra – TRS) supports the overall plant HCPLF value of 0.5g.

The success paths used for the SMA are taken conservatively in many cases, and credit for operator actions for events at 0.5g review level earthquake has been avoided. Thus, the results are valid without operator intervention, which indicates a strong point of the AP1000 design to mitigate seismically induced core damage and large release sequences.

All SMA sequences are evaluated with loss of offsite power and loss of onsite AC power leading to a station blackout event. The plant design is shown to be robust against seismic event sequences each of which contain station blackout coupled with other seismic or random failures.

19.55.6.2 AP1000 SMA Insights

The SMA results also point out the following insights:

1. Design Features

   The AP1000 design provides some aspects that make the plant more robust against the review level earthquakes. Namely:

   - Reactor trip is assured without the actuation signal due to the loss of offsite power occurring and rods inserting by gravity.

   - PRHR system valves fail open without actuation signal following loss of power/loss of instrument air. Thus, PRHR cooling is immediately available.

   - CMT system valves fail open without actuation signal following loss of power/loss of instrument air. Thus, CMT injection is immediately available.

   Thus, three key mitigating systems, reactor trip, PRHR cooling, and CMT injection are available with high confidence and low probability of failure, without dependence on actuation signals immediately after a review level seismic event.

   Moreover, the passive containment cooling system air operated valves also fail open in a review level earthquake, due to loss of offsite power/instrument air. As a result, the passive containment cooling system is automatically actuated and has enough water inventory to last for 72 hours.

2. DC System Fragility

   Control rods, PRHR, CMT, and passive core cooling systems would be operational after potential loss of protection and safety monitoring system (PMS) or DC control power. Thus, the plant can successfully mitigate a transient event even with a failure of PMS or DC control power. However, the DC control power system HCLPF is the same as the plant HCLPF (0.50g). This HCLPF has the potential to become a driving failure, if it were to be coupled with a LOCA event with low HCLPF. However, no such low HCLPF LOCA events are identified in the current model.

3. Importance of Valve Room Fragilities

Fragility of certain valve rooms where the passive core cooling system valves are concentrated becomes an important factor; the SMA model depends on the successful functioning of these valves to mitigate LOCA accidents. These rooms are labeled as 11206/11207 and contain CMT, accumulator, IRWST injection, and cavity recirculation valves. Since the HCLPF of these rooms is relatively high, compared to the plant HCLPF value, the seismic failure of many passive core cooling system valves does not become a contributor to plant HCLPF.

4. Operator Actions

Operator actions are not credited in the SMA model for the 0.50g review level events. Inclusion of operator actions in the models would provide additional success paths, such as manual actuation of the automatic depressurization system (ADS) after failure of CMTs to inject. However, this inclusion would not affect the plant HCLPF or the major conclusions of the SMA. Thus, the AP1000 design is already robust with respect to its response to seismic events, even without taking credit for operator actions.

5. IRWST Failure

This failure is modeled to render PRHR, gravity injection, and recirculation systems inoperable. Thus, it becomes a single point failure that affects both the transient (e.g. LOSP events) and LOCA success paths. Failure of IRWST is modeled as a part of gross structural failure, as well as in PRHR and gravity injection system fault trees. The IRWST HCLPF is 0.71g and therefore significantly above the plant level HCLPF.

Additionally, an argument can be made that when the IRWST fails, its inventory would end up in the containment cavity and can be used to recirculate cavity water back into the RCS, leading to successful core cooling. Although this scenario is plausible and credible, such success sequences (e.g. sequences where gravity injection is skipped, directly going into cavity recirculation) are not analyzed in the AP1000 PRA. For this purpose, no credit for such a success path is taken in the present model.

5. Large Fission Product Release

The large fission product release is driven by the same seismic sequences that dominate the plant core damage. This is due to either the nature of the initiating event (such as gross structural failure initiating event, EQ-STRUC), or postulated containment failure following a reactor vessel failure (RVFA) (such as EQ-RVFA initiating event or some ATWS sequences leading the RVFA). Failure of containment isolation or containment cooling system due to their system components or system actuation failures does not dominate the plant large release HCLPF.

19.55.7 References

19.55-1 "SECY-93-087 - Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," USNRC Memorandum, July 21, 1993, Chilk to Taylor.

19.55-2 Budnitz, R. J., et al., "An Approach to the Quantification of Seismic Margins in Nuclear Power Plants," NUREG/CR-4334, UCID-20444, August 1985.

19.55-3 Advanced Light Water Reactor Utility Requirements Document, Volume III, ALWR Passive Plant, Chapter 1, Appendix A, PRA Key Assumptions and Groundrules, Revisions 5 & 6, Issued December 1993.

19.55-4 "A Methodology for Assessment of Nuclear Power Plant Seismic Margin," Electric Power Research Institute, EPRI NP-6041, October 1988.

19.55-5 APP-GW-GL-022, Revision 8, AP1000 Probabilistic Risk Assessment, Westinghouse Electric, LLC, August 2007.

Table 19.55-1

SEISMIC MARGIN PARAMETERS AND HCLPF VALUES

Description	Median pga[1]	βc	HCLPF value pga[1]	Basis
Building/Structures				
Shield Building - Tension Ring	-	-	0.73	[2]
Shield Building - Air Inlet	-	-	0.71	[2]
Shield Building - Conical Roof	-	-	0.71	[2]
Shield Building - PCS Tank	-	-	0.81	[2]
Shield Building – SC/RC Connection	-	-	>0.67	[2]
Shield Building - RC Cylindrical Wall	-	-	0.67	[2]
Steel Containment Vessel - Buckling	1.94	0.42	0.73	[3]
Steel Containment Vessel - Overturning	5.74	0.62	1.38	[3]
Containment Baffle - Support Failure	-	-	0.91	[4]
Interior Containment Structure & IRWST Tank	-	-	0.71	[4]
Exterior Walls of Auxiliary Building – Wall 1	-	-	0.97	[2]
Exterior Walls of Auxiliary Building – Wall 11	-	-	0.88	[2]
Primary Components				
Reactor Pressure Vessel	-	-	0.56	[4]
Reactor Pressure Vessel Supports	1.58	0.35	0.71	[3]
Reactor Internals and Core Assembly (includes fuel)	1.5	0.51	0.5	[5]
Control Rod Drive Mechanism (CRDM)	2.2	0.51	0.7	[5]
Steam Generator	-	-	0.54	[4]
Steam Generator Support Column Buckling	1.14	0.33	0.54	[3]
Steam Generator Lower Lateral Support	1.23	0.34	0.57	[3]
Steam Generator Intermediate Supports	1.17	0.30	0.59	[3]
Pressurizer Supports	-	-	0.58	[4]
Pressurizer Upper Support Weld	1.02	0.31	0.50	[3]
Pressurizer Upper Support Strut	1.11	0.29	0.56	[3]

Table 19.55-1

SEISMIC MARGIN PARAMETERS AND HCLPF VALUES

Description	Median pga[1]	βc	HCLPF value pga[1]	Basis
Pressurizer Lower Support Strut	1.41	0.29	0.72	[3]
Reactor Coolant Pump[9]	2.2	0.51	0.68	[5]
Reactor Coolant Pump Heat Exchanger	-	-	0.55	[2]
Mechanical Equipment				
Polar Crane	-	-	0.55	[2]
Piping - Support Controlled	3.3	0.61	0.81	[5]
Cable trays - Support Controlled	2.2	0.61	0.54	[5]
Accumulator Tank	2.2	0.46	0.76	[5]
Core Make Up Tank	-	-	0.87	[4]
Heat Exchanger (PRHR)	-	-	1.11	[4]
Valves				
Higher than El. 100'	3.3	0.61	0.81	[5]
Equal to or Lower than El. 100'	-	-	1.02	[4]
Passive Containment Cooling System	-	-	0.67	[2]
Electrical Equipment				
Non-Sensitive to High Frequency Excitation	-	-	0.5	[6]
Sensitive to High Frequency Excitation	-	-	0.52	[6]
Ceramic Insulators[7]	0.2	0.35	0.09	[8]

Notes of Table 19.55-1:

[1] pga is the free field peak ground acceleration level for the seismic event

[2] HCLPF based on conservative deterministic failure margin approach

[3] HCLPF based on probabilistic fragility analysis

[4] HCLPF based on deterministic approach

[5] HCLPF based on URD recommended generic fragility data

[6] HCLPF based on design margin, code requirements and test margins inherent to the seismic qualification testing. Qualification testing with 99% confidence on the TRS will be limited to 0.3g.

[7] The capacity of the ceramic insulators is less than the review level earthquake of 0.5g. The failure of the ceramic insulators is considered in the PRA analysis.

[8] HCLPF based on recognized generic fragility data

[9] Reactor Coolant Pump Support HCLPF value is controlled by Steam Generator Support.

Table 19.55-2

BASIC EVENTS HCLPF VALUES

BE ID	BE Description	HCLPF [g]	Source
EQ-AB-EXTWALL	Failure of Auxiliary Building Exterior Wall	0.88	Exterior walls of auxiliary building, limiting values between *wall 1* and *wall 11*
EQ-AB-FLOOR	Failure of Auxiliary Building Floor	0.88	Same as AB exterior wall
EQ-AB-INTWALL	Failure of Auxiliary Building Interior Wall	0.88	Same as AB exterior wall
EQ-ACC-CV28	Accumulator Check Valves 28A and 28B Fail	1.02	In rooms 11206/11207, below elevation 100'
EQ-ACC-CV29	Accumulator Check Valves 29A and 29B Fail	1.02	In rooms 11206/11207, below elevation 100'
EQ-ACC-TANKS	Accumulator Tanks Fail	0.76	
EQ-ACDISPANEL	120 Volt AC Distribution Panels Fail	0.5	Limiting value among those provided for electrical equipment.
EQ-ADS-S1MOVS	ADS Stage 1 MOVs RCS-PL-V001A/B and RCS-PL-V011A/B Fail	0.81	In rooms 11603/11703, above elevation 100'
EQ-ADS-S2MOVS	ADS Stage 2 MOVs RCS-PL-V002A/B and RCS-PL-V012A/B Fail	0.81	In rooms 11603/11703, above elevation 100'
EQ-ADS-S3MOVS	ADS Stage 3 MOVs RCS-PL-V003A/B and RCS-PL-V013A/B Fail	0.81	In rooms 11603/11703, above elevation 100'
EQ-ADS-S4VALVES	ADS Stage 4 Squib Valves 4A/B/C/D Fail	0.81	In rooms 11301/11302, above elevation 100'
EQ-BAF-SUPP	Failure of Containment Baffle Support	0.91	
EQ-BAT-RACK	Battery Racks Fail	0.5	Limiting value among those provided for electrical equipment.
EQ-BATTERY	250 Vdc Batteries Fail	0.5	Limiting value among those provided for electrical equipment.

Table 19.55-2

BASIC EVENTS HCLPF VALUES

BE ID	BE Description	HCLPF [g]	Source
EQ-CABINETS	PMS Cabinet Fail	0.5	Limiting value among those provided for electrical equipment.
EQ-CABLETRAY	Cable Trays Fail	0.54	
EQ-CAS-AOV-1415	Containment CAS Isolation Valves AOV 14 and 15 Fail	0.81	In rooms 12405/11400, above elevation 100'
EQ-CER-INSULATOR	Seismically induced failure of ceramic insulators	0.09	
EQ-CMT-AOV	CMT AOV 14A/B and 15A/B Fail by Seismic Event	1.02	In rooms 11206/11207, below elevation 100'
EQ-CMT-CV	CMT CV 16A/B or 17A/B Fail by Seismic Event	1.02	In rooms 11206/11207, below elevation 100'
EQ-CMT-LEVELSWT	CMT Level Switch Fails	0.5	Limiting value among those provided for electrical equipment.
EQ-CMT-TANKS	CMT Tanks Fail by Seismic Event	0.87	
EQ-CONTPR-SENSOR	Containment Pressure Sensor or Transmitter Fails	0.5	Limiting value among those provided for electrical equipment.
EQ-CORE-ASSEMBLY	Failure of Core Assembly	0.5	
EQ-CRDM	Failure of Control Rod Drive Mechanism	0.7	
EQ-CV-BUCKLE	Containment Vessel Buckling	0.73	
EQ-CV-INTER	Failure of the Interior (concrete) Structure of Containment	0.71	
EQ-CV-OVERT	Containment Vessel Overturning	1.38	
EQ-DCDISPANEL	250 Vdc Distribution Panel Fails	0.5	Limiting value among those provided for electrical equipment.
EQ-DCMCC	DC Motor Control Centers Fail	0.5	Limiting value among those provided for electrical equipment.
EQ-DC-SWBRD	250 Vdc Switchboard Fails	0.5	Limiting value among those provided for electrical equipment.

Table 19.55-2

BASIC EVENTS HCLPF VALUES

BE ID	BE Description	HCLPF [g]	Source
EQ-DVI-PIPES	Seismically Induced Failure of Both DVI Lines	0.81	
EQ-ELECTRONICS	PMS Electronic Fail	0.5	Limiting value among those provided for electrical equipment.
EQ-INSTR-PIPES	Failure of RCS Instruments Lines	0.81	
EQ-INVERTER	250 Vdc Inverters Fail	0.5	Limiting value among those provided for electrical equipment.
EQ-IRW-INJCV	IRWTS Injection CV 122A/B and 124A/B Fail by Seismic Event	1.02	In rooms 11206/11207, below elevation 100'
EQ-IRW-INJSQ	IRWTS Injection Squib Valves 123A/B and 125A/B Fail by Seismic Event	1.02	In rooms 11206/11207, below elevation 100'
EQ-IRW-RECCV	Sump Recirculation Check valves 119A/B Fail by Seismic Event	1.02	In rooms 11206/11207, below elevation 100'
EQ-IRW-RECMOV	Sump Recirculation MOVs 117A/B Fail by Seismic Event	1.02	In rooms 11206/11207, below elevation 100'
EQ-IRW-RECSQ	Failure of Recirculation Squib Valves 118A/B and 120A/B by Seismic Event	1.02	In rooms 11206/11207, below elevation 100'
EQ-IRWST-TANK	Failure of IRWST	0.71	
EQ-MSL-SENSOR	Main Steam Line Pressure Sensor or Transmitter Fails	0.5	Limiting value among those provided for electrical equipment.
EQ-PCC-TANK	Passive Containment Core Cooling Tank Fails	0.81	
EQ-POL-CRANE	Failure of the Polar Crane	0.55	
EQ-PRHR-AOV	Passive RHR AOVs PXS-PL-V108A and B Fail by Seismic Event	0.81	In room 11300, above elevation 100'
EQ-PRHR-HX	Failure of Passive RHR Heat Exchanger	1.11	
EQ-PRZR-FAILS	Seismically Induced Failures of the Pressurizer	0.5	Pressurizer upper support weld (limiting HCLPF among pressurizer components)

Table 19.55-2

BASIC EVENTS HCLPF VALUES

BE ID	BE Description	HCLPF [g]	Source
EQ-PRZR-LVTRANS	Seismically Induced Failure of Pressurizer Level Transmitter	0.5	Limiting value among those provided for electrical equipment.
EQ-PRZR-SENSOR	Pressurier Sensor Or Transmitter Fails	0.5	Limiting value among those provided for electrical equipment.
EQ-PRZR-SV	Pressurizer Safety Valves RCS-PL-V005A/B Fail Seismically	0.81	In rooms 11603/11703, above elevation 100'
EQ-RCP-FAILS	Reactor Coolant Pumps Fail	0.54	Same as SG due to connection between RCP & SG.
EQ-RCP-HX	Seismically Induced RCP HX Failure Inducing a LOCA	0.55	
EQ-RCS-PIPES	Failure of RCS Piping	0.81	
EQ-RV-FAILS	Reactor Pressure Vessel Fails	0.56	
EQ-RV-FUEL	Fuel in Reactor Vessel Fails	0.5	
EQ-RV-HDPK	Reactor Vessel Integrated Head Package Fails	0.7	Same as CRDM due to physical location
EQ-SG-FAILS	Seismically Induced Failures of the Steam Generators	0.54	
EQ-SGTR	Seismically Induced SGTR	0.54	Same as SG failure
EQ-SHBLD-ROOF	Shield Building Roof Fails	0.71	
EQ-SHBLD-WALL	Shield Building Wall Fails	0.71	Same as roof
EQ-SLB	Failure of Feed and Steam Pipes on Secondary Side	0.81	
EQ-TRSFSWITCH	Transfer Switches Fail	0.5	Limiting value among those provided for electrical equipment.
EQ-VFS-AOV-0304	VFS Containment Air Supply Isolation Valves AOV 03 and 04 Fail	0.81	In rooms 12452/11400, above elevation 100'
EQ-VFS-AOV-0910	VFS Containment Air Exhaust Isolation Valves AOV 09 and 10 Fail	0.81	In rooms 12452/11400, above elevation 100'

Table 19.55-2

BASIC EVENTS HCLPF VALUES

BE ID	BE Description	HCLPF [g]	Source
EQ-WLS-AOV-5557	WLS Cont. Sump Isolation Valves AOV 55 and 57 Fail	0.81	In rooms 11300/12244, above elevation 100'

Table 19.55-3

EQ-IEV-STRUC (EQSTR-02) HCLPF

		Original AP1000	Updated AP1000
1	EQ-AB-FLOOR	0.51g	0.88g
2	EQ-AB-EXTWALL	0.51g	0.88g
3	EQ-AB-INTWALL	0.51g	0.88g
4	EQ-BAF-SUPP	1.30g	0.91g
5	EQ-PCC-TANK	0.51g	0.81g
6	EQ-SHBLD-ROOF	0.51g	0.71g
7	EQ-SHBLD-WALL	0.51g	0.71g
8	EQ-CV-INTER	0.50g	0.71g
9	EQ-CV-BUCKLE	0.66g	0.73g
10	EQ-CV-OVERT	1.11g	1.38g
11	EQ-IRWST-TANK	0.50g	0.71g
12	EQ-POL-CRANE	0.77g	0.55g
	IE HCLPF=	0.50g	0.55g

Table 19.55-4

EQ-IEV-RVFA (EQRVF-02) HCLPF

		Original AP1000	Updated AP1000
1	EQ-DVI-PIPES	0.81g	0.81g
2	EQ-SG-FAILS	0.54g	0.54g
3	EQ-RCP-FAILS	0.68g	0.54g
4	EQ-PRZR-FAILS	0.55g	0.50g
5	EQ-RV-FUEL	0.50g	0.50g
6	EQ-RV-HDPK	0.70g	0.70g
7	EQ-RV-FAILS	0.64g	0.56g
	IE HCLPF =	0.50g	0.50g

Table 19.55-5

EQ-IEV-LLOCA HCLPF

		Original AP1000	Updated AP1000
1	EQ-PRHR-HX	0.76g	1.11g
2	EQ-RCS-PIPES	0.81g	0.81g
	IE HCLPF =	0.76g	0.81g

Table 19.55-6

EQ-IEV-SLOCA HCLPF

		Original AP1000	Updated AP1000
RCS Instrumentation Pipe Breaks	EQ-INSTR-PIPES	0.81g	0.81g
Secondary Line Breaks	EQ-SLB	0.81g	0.81g
SGTR	EQ-SGTR	0. 54g	0.54g
RCP HX	EQ-RCP-HX	-	0.55g
	HCLPF =	0.54g	0.54g

Table 19.55-7 **EQ-IEV-ATWS HCLPF**			
		Original AP1000	**Updated AP1000**
1	EQ-CORE-ASSEMBLY	0.50g	0.50g
2	EQ-CRDM	0.70g	0.70g
	HCLPF =	0.50g	0.50g

Table 19.55-8

SEQUENCE AND PLANT HCLPF

ET	Original AP1000	Updated AP1000
EQ-STRUC	EQSTR-02	0.55
	EQ-STRUC HCLPF	*0.55*
EQ-RVFA	EQRVF-02	0.50
	EQ-RVFA HCLPF	*0.50*
EQ-LLOCA	EQLLO-02	0.81
	EQLLO-03	0.81
	EQLLO-05	0.81
	EQLLO-06	0.81
	EQLLO-08	0.81
	EQLLO-09	0.81
	EQLLO-10	0.81
	EQLLO-11	0.81
	EQ-LLOCA HCLPF	*0.81*
EQ-SLOCA	EQSLO-02	0.54
	EQSLO-03	0.54
	EQSLO-04	0.54
	EQSLO-05	0.87
	EQ-SLOCA HCLPF	*0.54*
EQ-ATWS	EQATW-02	0.50
	EQATW-03	0.50
	EQATW-04	0.50
	EQATW-05	0.87
	EQATW-06	0.81
	EQATW-07	0.71
	EQ-ATWS HCLPF	*0.50*
EQ-LOSP	*All mixed cut sets (IE HCLP =0.09)*	*N/A*
	Plant HCLPF	***0.50***

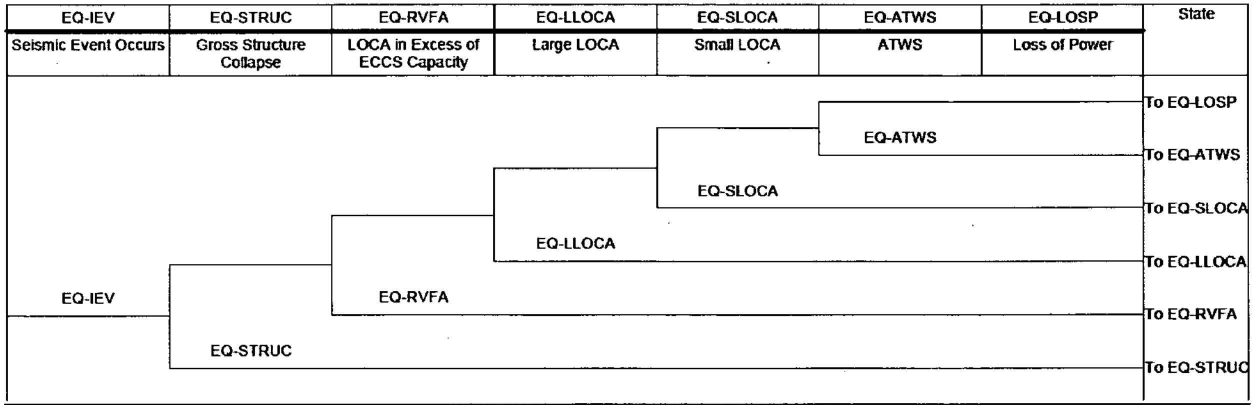

Figure 19.55-1

Seismic Initiating Event Hierarchy Tree

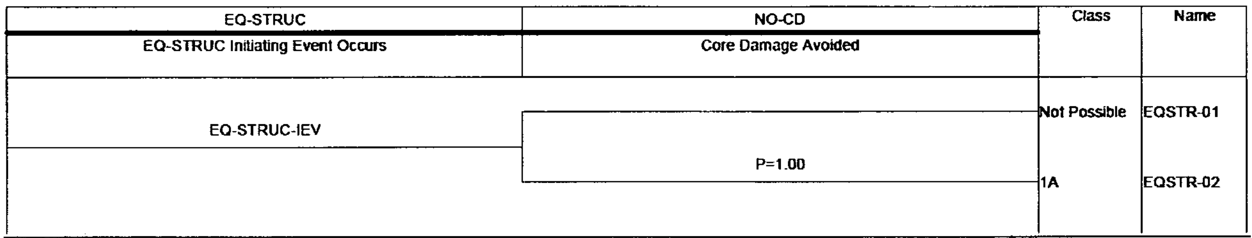

Figure 19.55-2

Seismic Induced Gross Structural Collapse Event Tree

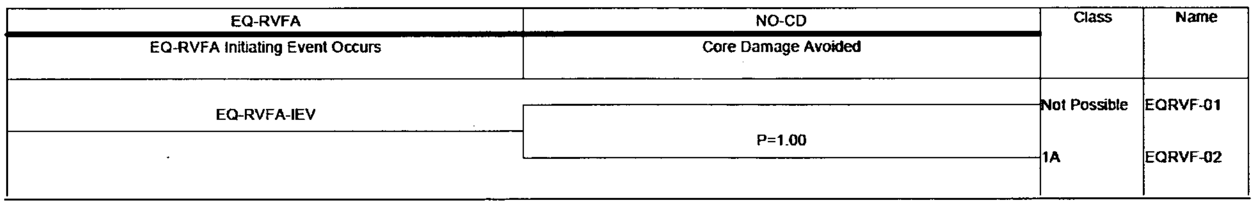

Figure 19.55-3

Seismic Induced Excessive LOCA Event Tree

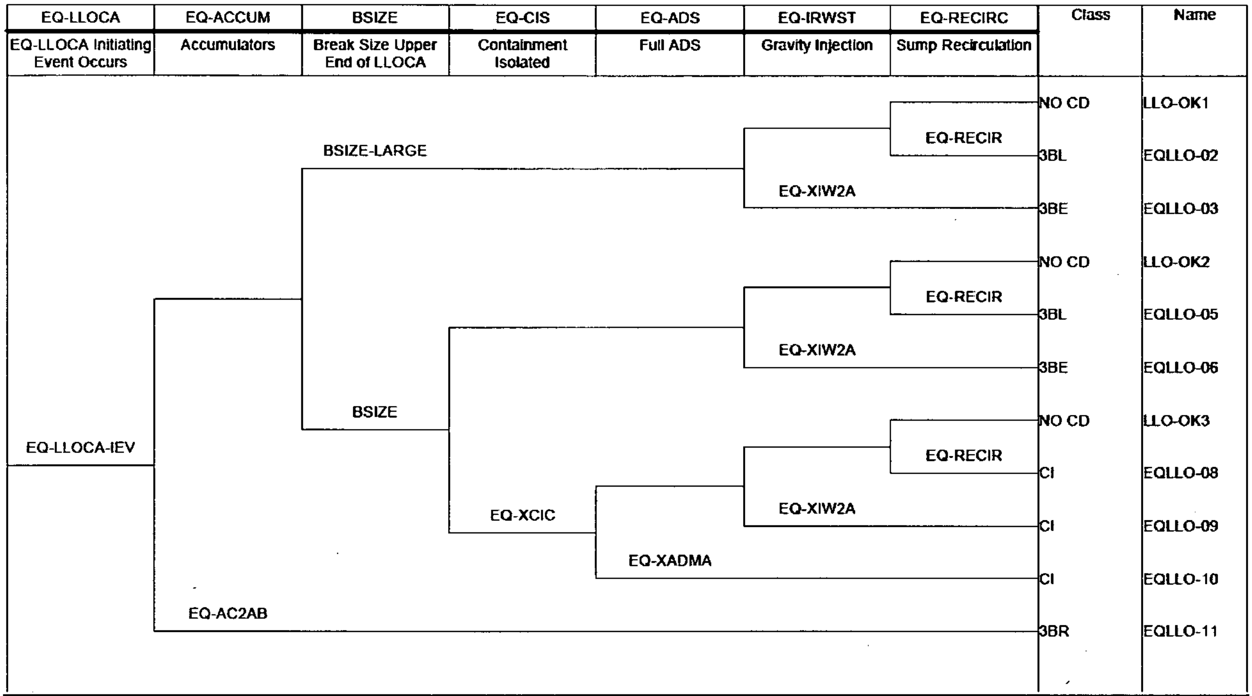

Figure 19.55-4

Seismic Induced Large LOCA Event Tree

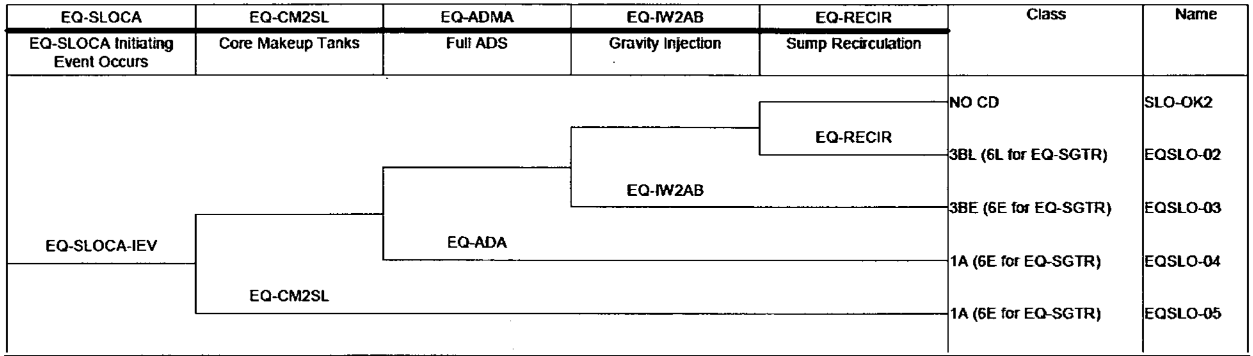

Figure 19.55-5

Seismic Induced Small LOCA Event Tree

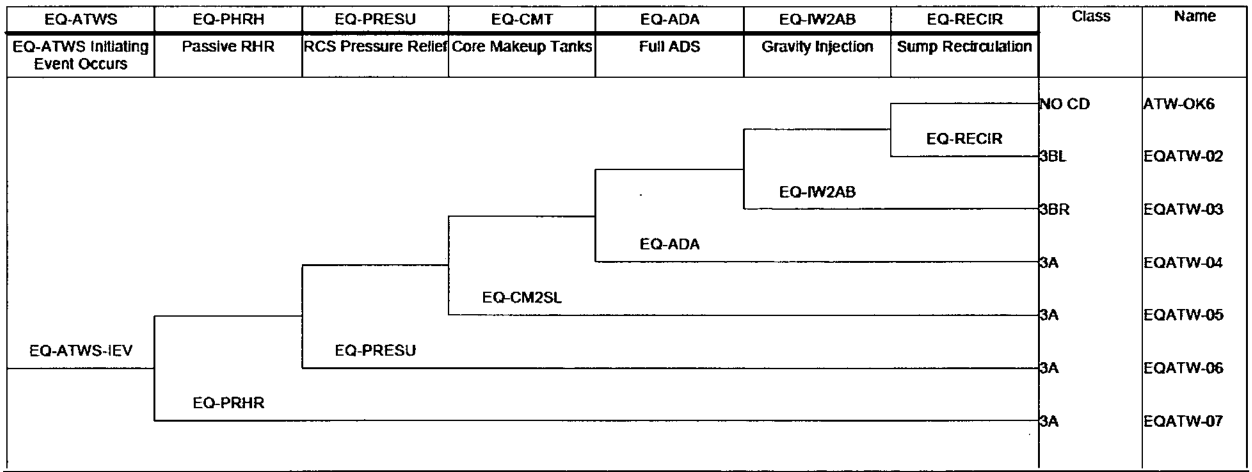

Figure 19.55-6

Seismic Induced ATWS Event Tree

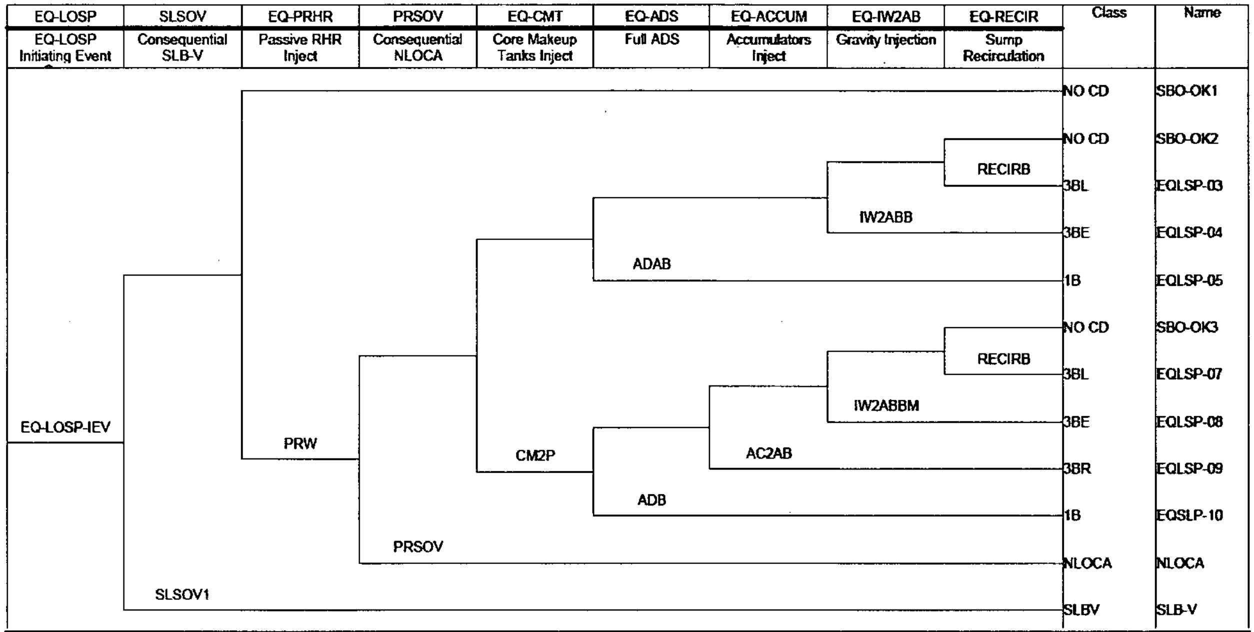

Figure 19.55-7

Seismic Induced LOSP Event Tree

19.59.10.5 Combined License Information

The Combined License applicant referencing the AP1000 certified design will confirm that the Seismic Margin Assessment analysis documented in Section 19.55 is applicable to the COL site. This will include a confirmation that the COL site seismic demand based on the site GMRS is enveloped by the Certified Seismic Design Response Spectra (CSDRS) seismic demand as defined by Tier 1 criteria for SSE as well as an assessment that no site specific effects such as seismically induced liquefaction settlements, slope stability, foundation failure, and relative displacements have the potential to lower the HCLPF values calculated for the certified design. Further evaluation will be required if the COL site is shown to be outside of the bounds of the SMA analysis documented in Section 19.55.

The Combined License holder referencing the AP1000 certified design will review differences between the as-built plant and the design used as the basis for the AP1000 seismic margins analysis prior to fuel load. A verification walkdown will be performed with the purpose of identifying differences between the as-built plant and the design. Any differences will be evaluated to determine if there is a significant adverse effect on the seismic margins analysis results. Spacial interactions are addressed by COL Information Item 3.7-3. Details of the process will be developed by the Combined License holder.

The Combined License holder referencing the AP1000 certified design should compare the as-built SSC HCLPFs to those assumed in the AP1000 seismic margin evaluation prior to fuel load. Deviations from the HCLPF values or assumptions in the seismic margin evaluation due to the as-built configuration and final analysis should be evaluated to determine if vulnerabilities have been introduced. The requirements to which the equipment is to be purchased are included in the equipment specifications. Specifically, the equipment specifications include:

1. Specific minimum seismic requirements consistent with those used to define the Table 19.55-1 HCLPF values.

   This includes the known frequency range used to define the HCLPF by comparing the required response spectrum (RRS) and test response spectrum (TRS). The test response spectra must be chosen so as to demonstrate that no more than one percent rate of failure would be expected when the equipment is subjected to the applicable seismic margin ground motion for the equipment identified to be applicable in the Seismic Margin Insights of the Site-Specific PRA. The range of frequency response that is required for the equipment with its structural support is defined.

2. Hardware enhancements that were determined in previous test programs and/or analysis programs will be implemented.

The Combined License holder referencing the AP1000 certified design will review differences between the as-built plant and the design used as the basis for the AP1000 PRA and Table 19.59-18 prior to fuel load. If the effects of the differences are shown, by a screening analysis, to potentially result in a significant increase in core damage frequency or large release frequency, the PRA will be updated to reflect these differences.

Based on site-specific information, the COL should also reevaluate the qualitative screening of external events (PRA Section 58.1). If any site-specific susceptibilities are found, the PRA should be updated to include the applicable external event. The Combined License information requested in this subsection has been partially addressed in APP-GW-GLR-101 (Reference 19.59-4), and the applicable changes are incorporated into the DCD. Additional work is required by the Combined License applicant to address the aspects of the Combined License information requested in this subsection as delineated in the following paragraph:

> The Combined License applicant will confirm that the High Winds, Floods, and Other External Events analysis documented in Section 19.58 is applicable to the COL site. Further evaluation will be required if the COL site is shown to be outside of the bounds of the High Winds, Floods, and Other External Events analysis documented in Section 19.58.

The Combined License holder referencing the AP1000 certified design will review differences between the as-built plant and the design used as the basis for the AP1000 internal fire and internal flood analysis prior to fuel load. Differences will be evaluated to determine if there is significant adverse effect on the internal fire and internal flood analysis results.

The Combined License applicant referencing the AP1000 certified design will develop and implement severe accident management guidance using the suggested framework provided in APP-GW-GL-027, "Framework for AP1000 Severe Accident Management Guidance," (Reference 19.59-2). The Combined License information requested in this subsection has been partially addressed in APP-GW-GLR-070 (Reference 19.59-1), and the applicable changes are incorporated into the DCD. APP-GW-GLR-070 closes the development portion of this COL item. Additional work is required by the Combined License applicant to address the aspects of the Combined License information requested in this subsection as delineated in the following paragraph:

> The Combined License applicant will implement the AP1000 Severe Accident Management Guidance from APP-GW-GLR-070 on a site-specific basis.

The Combined License holder referencing the AP1000 certified design will perform a thermal lag assessment of the as-built equipment listed in Tables 6b and 6c in Attachment A of APP-GW-GLR-069 (Reference 19.59-5) to provide additional assurance that this equipment can perform its severe accident functions during environmental conditions resulting from hydrogen burns associated with severe accidents. This assessment is performed prior to fuel load and is required only for equipment used for severe accident mitigation that has not been tested at severe accident conditions. The Combined License holder will assess the ability of the as-built equipment to perform during severe accident hydrogen burns using the Environment Enveloping method or the Test Based Thermal Analysis method discussed in EPRI NP-4354 (Reference 19.59-3).

PRA Revision:
None

Technical Report (TR) Revision:
None