SYSTEM 80+ ALWR

A PRA-BASED SEISMIC MARGIN EVALUATION

ADDITIONAL CLARIFICATIONS IN RESPONSE TO
NRC REQUESTED ITEMS

Prepared By:

ABB Combustion Engineering

9302240272 930216
PDR ADOCK 05200002
A PDR

CONTENTS

SECTION 1.0

NRC Request: Provide an overview of the general approach

Below is a description of an overview of the general approach for performance of a PRA-Based seismic margin analysis of the System 80+ design. This approach consists of 5 main tasks described below:

TASK 1- DEVELOP INITIAL SEISMIC EVENT AND FAULT TREES: Under this task, initial event and fault trees assuming an earthquake as an initiating event will be developed. These models will consider secondary failure effects which could impact functionality of equipment in various branches. Examples are failure of structures or system interaction concerns.

The construction of these trees will result in an initial set of Structures, Systems and Components (SSCs), whose seismic fragility levels will need to be evaluated.

TASK 2- PRUNNING OF THE SEISMIC EVENT AND FAULT TREES: Under this task, both systems engineers as well as seismic fragility engineers will review the models developed under task 1, for prunning purposes. For this purpose, the experience of the seismic fragility engineers will be relied upon to modify the models, if for instance based on past experience it would be obvious that certain components in certain paths will have excessively low seismic fragilities, hence contributing to low sequence or plant level HCLPFs. For such cases alternate routes will be considered if acceptable by the system engineer. By the same token, the opposite may be true, i.e. some components or systems not included in the initial model may exhibit large HCLPFs, thus improving sequence or plant level HCLPFs, once included in the model as an alternate path.

To the extent possible, prunned out SSCs will be represented in the model by surrogate fragilities. For this purpose, generic fragilities based on past PRAs as summarized in the EPRI Utility Requirements Document (Appendix A, Table A.3-4) will be used to represent rugged SSCs.

The outcome from this task will be a revised SSC list for which seismic HCLPFs and fragilities will be computed.

SECTION 1.0 (Cont.)

Significant interaction between the system engineers and the seismic fragility engineers will take place during the execution of this task.

TASK 3- DETAILED SEISMIC FRAGILITY ASSESSMENT: Under this task detailed fragility evaluations will be performed for SSCs identified under task 2 above.

SSC fragilities will be determined based on a 2-phase approach. Initially, approximate fragilities will be developed using an approach recently developed by Dr. R. P. Kennedy. This approach makes use of the EPRI Conservative Deterministic Failure Methodology (CDFM) as outlined in EPRI-NP-6041-SL, Rev. 1 report. The CDFM methodology will be used to compute HCLPF values for all SSCs on the list. Using these HCLPFs and assumed value of *B*c (composite uncertainty), approximate fragility curves will be computed. The details of this method are given in section 2.0.

Once approximate fragilities are computed, the PRA model will use these values to determine dominant contributors to seismic risk. For these dominant contributors, detailed fragilities will be computed using rigorous techniques and the PRA model will be re-evaluated.

Initially, plant SSC HCLPFs will be evaluated using a Review Level Earthquake of 0.6g. The CMS3 spectral shape (modified NUREG 0098 spectral shape) will be anchored to 0.6g. Rock conditions are chosen initially, since for any given site condition, they provide a broad-band input and hence it is likely to cover a wide range of frequencies of interest. Once HCLPF values for this site condition are computed, the effects of potential soil conditions on altering certain SSC HCLPFs as well as their effect on changing ranking of dominant contibutors will be addressed. Further discussion on this subject is provided in section 4.0.

TASK 4- CONTAINMENT EVALUATION: Under this task, seismic failure modes, sequences and vulnerabilities involving containment, containment functions, and containment systems will be evaluated. Gross structural failures as well as penetration stresses will be determined.

SECTION 1.0 (Cont.)

The NRC suggested approach for evaluation of containment Isolation and Bypass will be used in the margin analysis. This approach requires identification of each cutset whose HCLPF is less than 0.6g considering random failures using either the Min/Max or the convolution approach. If such cutsets are identified, then active and passive systems important to containment isolation whose failure would lead to an unscrubbed release will be identified. In addition, the ruggedness of potential containment bypass paths will be determined to see if they exhibit HCLPF below 0.6g.

The result will be reporting of any systems or components identified above, and discussing the potential effects associated with the combination of sequences identified in the original cutsets with those of containment bypass and isolation.

TASK 5- DETERMINATION OF PLANT VULNERABILITIES: Under this task, various path, sequence and plant level seismic vulnerabilities will be identified by both the Min/Max and the convolution approach. Since component fragilities will be determined using the CDFM approach utilizing the approximation technique suggested by Dr. Kennedy, the option of using both the Min/Max approach and the convolution approach will be open.

Since System 80+ detailed design is not complete at this stage, should this exercise result in plant SSC HCLPFs below the desired level of 0.6g, or certain SSCs contributing to unacceptably high seismic risk numbers, then the insights from this evaluation will be used to provide committments in design in order to achieve desired HCLPF values.

SECTION 2.0

NRC Request: ***Provide details of the approach developed by Dr. R. P. Kennedy to develop approximate fragilities using the EPRI CDFM methodology***

This section provides an overview of this approach. Attachment 1 to this section provides the presentation slides and reference material used by Dr. Kennedy to present this approach.

OVERVIEW

Approximate seismic fragility curves can be computed using deterministic HCLPF evaluation assuming that the fragility is lognormally distributed. It can be shown that this approximate methodology will in general result in risk numbers which are conservative by a factor of no more than 2, assuming a reasonable range of variabilities (when compared with risk numbers from exact fragilities).

In a rigorous fragility evaluation, once median acceleration estimates as well as estimates of randomness (Br) and uncertainty (Bu) are determined, one can compute HCLPF as follows:

$$\text{HCLPF} = (\text{Median acc.}) \exp(-1.65\,(Br + Bu)) \qquad (1)$$

To determine the mean risk only, and relative ranking of components that contribute to the mean risk, one does not need to separate variability into randomness and uncertainty. As such, both variabilities are lumped into a composite variability, Bc. For the typical range of Bc, equation (1) can be approximated as:

$$\text{HCLPF} = (\text{Median acc.}) \exp(-2.3\,Bc) \qquad (2)$$

Assuming a range on Bc = 0.3 to 0.5 (typicall of computed values for Bc), the corresponding range on (Median/HCLPF) ratio from (2) above will be in the 2.0 to 3.2 range.

Using an average Bc = 0.4 (half way between 0.3 and 0.5), equation (2) will result in:

$$\text{Median (acc.)} = 2.5\ \text{HCLPF} \qquad (3)$$

SECTION 2.0 (Cont.)

This HCLPF is usually denoted as $HCLPF_{50}$ corresponding to an earthquake response spectrum which has 50% probability of being exceeded at any frequency. In contrast, the HCLPF value computed using the EPRI CDFM approach is denoted by $HCLPF_{84}$. This corresponds to an earthquake response spectrum which only has 16% probability of being exceeded at any frequency. The relationship between these two HCLPFs is given by:

$$HCLPF_{84} = HCLPF_{50} \exp(B_{csa}) \quad (4)$$

Where, B_{csa} corresponds to the composite variability associated with spectral shape.

Using the value of B_{csa} of 0.18 which was used to develop the CDFM methodology, one can estimate:

$$HCLPF_{50} = HCLPF_{84}/1.2 = CDFM/1.2 \quad (5)$$

Therefore, using equations (3) and (5), one can determine:

$$\text{Median (acc.)} = 2.1\ CDFM \quad (6)$$

Having determined Median (acc.) and an assumed value of $B_c = 0.4$ for composite variability, one can construct approximate fragility curves for various SSCs based on CDFM HCLPF only.

It can be shown by either exact or approximate convolution techniques, that the resulting risk numbers from these approximate fragilities are generally on the conservative side when compared with exact values by no more than a factor of 2. Example problems demonstrating this conclusion are given in attachment 1. Even with extremely large B_c, approximate risk numbers are shown to be less than a factor of 2 too large.

SECTION 3.0

NRC REQUEST: ***Provide justification for selection of spectral shape to be used in the margin evaluation***

This section provides the justification for using CMS3 as the spectral shape in margin evaluation of System 80+ design.

Control Motion Spectrum 3 (CMS3) is a modified NUREG 0098 spectral shape. The modification is done by extending the flat portion of the spectrum from 8 Hz to 15 Hz in order to introduce more high frequency content typical of what might be expected from an Eastern U.S. earthquake. This spectrum is shown in figure 3.1 anchored to a PGA of 0.3g. CMS3 is one of the 3 control motions used in the design of System 80+.

For margin evaluation using the guidelines of the EPRI SMA approach, the SME (or RLE) is defined at an 84% Non Exceedance Probability (NEP). Two components contribute to this definition. First, is the level at which the PGA is set. Second, is the spectral shape once the PGA is defined. To approximately achieve an 84% NEP SME, one can either set the PGA level at 84% NEP and use a median spectral shape, or alternatively set the spectral shape at 84% NEP and use a median PGA. However, it is generally believed that in order to obtain 84% NEP at all frequencies, the first alternative is desirable. Setting both the PGA and the spectral shape at 84% NEP results in excessive NEP (approximately > 95% NEP).

The design basis of 0.3g for ALWRs is defined at 84% NEP. Since the RLE is set at twice the design basis PGA, it also represents an 84% NEP PGA for margin evaluation. The NUREG 0098 spectral shape is generally viewed as a median spectral shape, where as R.G. 1.60 spectral shape was developed based on an 84% NEP constructed through the records which formed its basis.

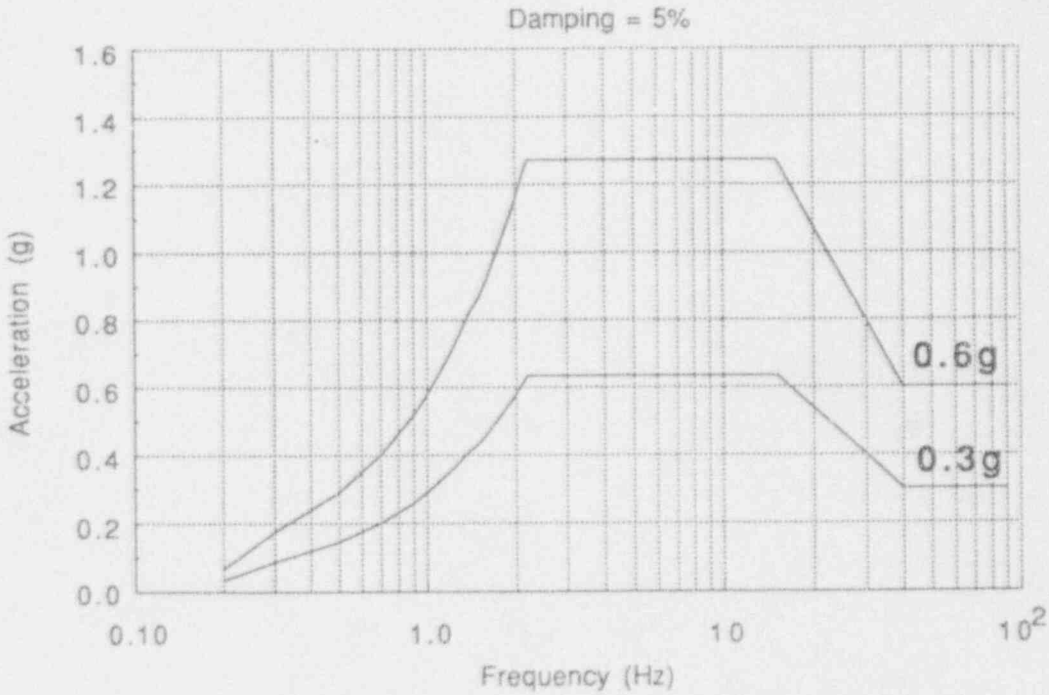
Therefore, it is concluded that in order to meet the intent of the margin evaluation philosophy, the demand is to be defined as 84% NEP consistently at all frequencies. By choosing a NUREG 0098 spectral shape (representing 50% NEP) anchored to a PGA of 0.6g (representing 84% NEP) one arrives at an approximate 84% NEP RLE at all frequencies.

SECTION 3.0 (CONT.)

By choosing a R.G. 1.60 spectral shape anchored to 0.6g, one would have an RLE with approximate NEP in excess of 95% in the lower frequencies (2.5 to 9 Hz), gradually reducing to an 84% NEP at PGA levels.

The choice of a NUREG 0098 spectral shape for margin evaluation of System 80+ is also consistent with the spectral shape recommended in NUREG-1407 for Seismic IPEEE for existing plants, if the seismic margin methodology is chosen.

FIGURE 3.1: CMS3 Spectral Shape anchored to both 0.3g (Design Basis) and 0.6g (RLE), 5% Damped



SECTION 4.0

NRC REQUEST: ***Provide a position regarding applicability of the margin evaluation insights to soil conditions as well as rock conditions***

This section provides the requested position on the applicability of the margin evaluation insights to soil site conditions as well as rock conditions.

The System 80+ seismic margin evaluation will be performed in two stages. Initially, the margin evaluation will be performed using rock site conditions. As such, initially a broad-band input motion is used to determine SSC HCLPFs , approximate fragilities, and seismic risk numbers for components covering a wide frequency range of interest. At this stage, the natural frequencies of all SSCs of interest, as well as the contribution to HCLPF from the capacity side for each of these SSCs will also be available. Once this data is available, the effect of soil conditions on potentially reducing HCLPFs due to higher demands, or altering the relative ranking of the dominant contributors will be adressed in the following manner.

The initial margin evaluation corresponding to rock conditions, is expected to result in HCLPF values in the range of 0.7g to 0.8g or higher (probably in excess of the desired HCLPF level of 0.6g). This is due to the observation that the System 80+ design basis spectra are fairly high (about 0.5g ZPA at foundation elevation). The high design basis spectra is primarily due to the convolution process associated with shallow soil sites when the control motion is defined at top of a hypothetical rock outcrop. Figure 4.1 shows the design basis broadened spectra at foundation elevation superimposed with the design basis CMS3 rock spectrum as well as RLE CMS3 rock spectrum anchored to 0.6g. Included in the same plot are the results of one of the soil cases which contributes to the highest spectral peaks at some narrow frequency (about 2.0 Hz.).

For the initial margin evaluation, it is therefore desirable to have a broad-band input in order to cover a wide frequency band of interest. Any one soil site is liable to have spectral peaks in a narrow frequency range, because of filtering effects associated with SSI phenomenon (e.g. soil case shown in Figure 4.1).

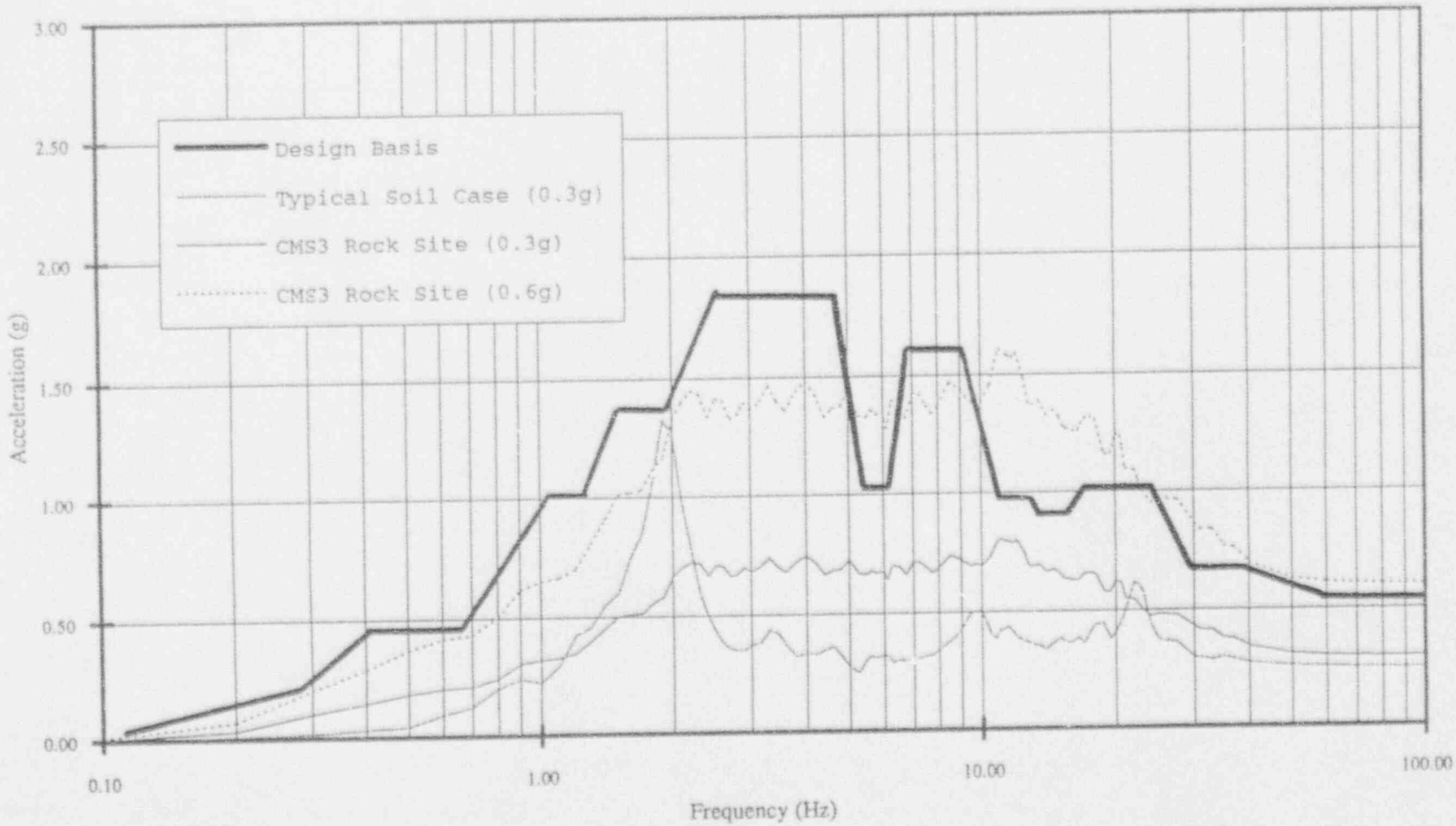
SECTION 4.0 (CONT.)

Once the margin assessment is completed using the rock site conditions, HCLPF values and natural frequencies for all SSCs of interest will be available. Using this data as well as the design basis demand data available for the envelope of all cases (12 soil and 1 rock case) versus rock case, allowing for frequency shifts resulting from higher RLE motions going through soil, and allowing for spectral peak clipping and pick shifting, one can approximately determine in what frequency range and for which components, soil site conditions could result in higher demand and hence potentially lower HCLPFs. If this estimation of reduced HCLPFs is below the desired level of 0.6g for any SSC, then margin assessments corresponding to the governing soil conditions will be repeated resulting in accurate estimation of HCLPFs for soil site conditions.

If detailed margin evaluations are required to be performed for one or more soil site conditions, then these will also utilize a NUREG 0098 spectral shape adjusted to represent soil conditions (i.e. more low frequency content). This control motion will also be anchored to 0.6g PGA.

In this fashion, the effects of soil site conditions potentially affecting HCLPFs for certain components will be considered and evaluated.

Figure 4.1: Comparison of Example Design Basis Spectra with CMS3 Raw Spectra for Both Design Basis and RLE and a Typical Individual Soil Case Response Spectrum (Elev. +50', Top of Basemat, E-W Direction, 5% Damped)



SECTION 5.0

NRC REQUEST: Provide clarification on the notation of $HCLPF_{84}$ versus CDFM HCLPF

This section provides clarification on the subject.

The term HCLPF refers to High Confidence of Low Probability of Failure. This term is refered to a 95% (high) confidence level that the probability of failure will not exceed 5% (low probability of failure). Hence HCLPF is sometimes denoted as the 95/5 failure acceleration threshold.

Using the EPRI CDFM approach one computes HCLPF. However, inherent in the CDFM approach is the definition of ground motion which is defined as 84% Non-Exceedance Probability (NEP). Hence, HCLPF as computed by the EPRI CDFM approach is sometimes denoted as $HCLPF_{84}$.

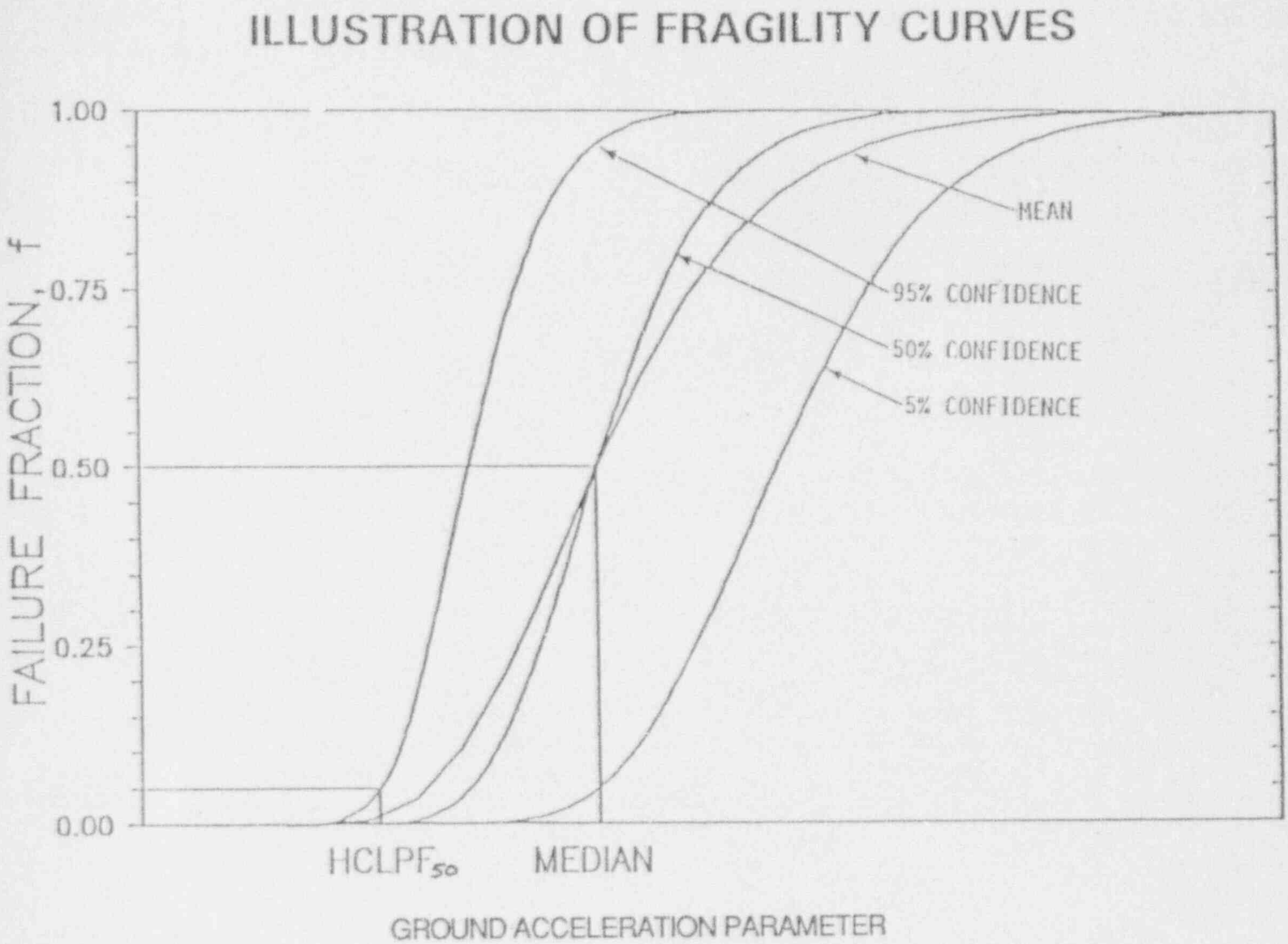
When one computes median fragility estimates, all parameters are assumed as median. This includes the definition of control motion meaning that at all frequencies of interest (if fragility is defined in terms of PGA), there is 50% NEP. In defining a family of fragility curves, one usually presents a number of curves ranging from 5% to 95% confidence level. On these plots, the acceleration level which represents the 5% probability of failure on a 95% confidence curve is denoted as HCLPF also. However, due to the definition of the input motion being 50% NEP, this HCLPF value is sometimes denoted as $HCLPF_{50}$ (see Figure 5.1).

The difference between this $HCLPF_{50}$ and $HCLPF_{84}$ as obtained from EPRI CDFM approach is purely due to the definition of the input motion, specifically whether it is defined at 50% NEP or 84% NEP. The relationship between these two HCLPF values is given as:

$$HCLPF_{84} = HCLPF_{50} \exp(\beta_{csa})$$

Where, β_{csa} is the composite variability associated with spectral shape.

Figure 5.1: Typicall Fragility Curves



ATTACHMENT 1 TO SECTION 2.0

Additional Presentation Slides in Support of the Proposed Methodology

Presented At:
Post-Symposium Seminar

on

FRAGILITY EVALUATION FOR PROBABILISTIC RISK ASSESSMENT FOR NUCLEAR POWER PLANTS

Presented By:

Dr. R. P. Kennedy
RPK Structural Mechanics Consulting, Inc.
10871 Villa Terrace
Yorba Linda, CA 92686

Session K14

Suggested Simplifications

Vugraphs

Suggested Simplifications

Robert P. Kennedy

Treatment of Variabilities

- To Determine Mean Risk and Components Which Dominant Contribution to Mean Risk, One Doesn't Need to Separate Variability into Randomness and Uncertainty
- Both Variabilities Can Be Lumped Into Composite Variability

Fragility Analysis (Cont.)

- HCLPFs can be calculated as follows:

$$HCLPF = \check{a}\, e^{-1.65(\beta_r + \beta_u)}$$

$$HCLPF = \check{a}\, e^{-2.3\, \beta_c}$$

Screening

- Aggressively Screen-Out Higher Capacity Components From Fragility Development Using EPRI-NP-6041-SL

- Set Screening Level Sufficiently High That Either:

    - Several Important Components Have $HCLPF_{84}$ Levels Below Screening Level

    - Seismic Risk Based on Screening Level is Adequately Low

Screening Procedure

- Screened out components may still contribute to mean frequency of core damage, e.g.,
  - Several screened out components could have HCLPFs close to the screening limit

- Screen using NP-6041 screening guidelines as for SMA
  - If use first column of Tables 2-3 and 2-4 recommend adding 1 additional element to PRA

$$\text{median } S_a = 1.3\text{ g}$$
$$\beta_c = 0.3$$

Conservative Surrogate Fragility

$$HCLPF_{50} = \frac{CDFM}{1.2} = \frac{0.8g}{1.2} = 0.67g$$

$\beta_C = 0.3$ (Conservative Surrogate)

$$\text{Median } S_A = HCLPF_{50}\, e^{2.3\beta_C} = 2.0(0.67g) = 1.33g$$

Screening Procedure (Cont.)

- Likely that additional element added to seismic PRA will not significantly increase mean frequency of core damage for most EUS sites
  - Generally the increase will be less than $1 * 10^{-5}$ per year (and usually much less) for EPRI hazard curves
- Experience from past PRAs indicates that this surrogate element is adequate

Screening Procedure (Cont.)

- Sa capacity can be converted to pga capacity using the shape of the UHS for the site
- SRT can develop plant-specific equivalent component based on specific components being screened out
- Likely that some ccmponents functional/integrity failure modes will be screened out, but anchorage will require evaluation

Fragility Analysis

- Performed for components not screened out

- More detailed analysis will be required for significant contributors
  - Weaker components, where there is no redundancy
  - SRT should rank capacities based on judgement and discuss with systems engineers

- Interaction between seismic capability engineers and systems analysts will lead to more efficient fragility calculations

Approximate Probability of Failure Estimate (ie., Convolution of Hazard and Fragility Curves)

UCRL-CR-111478

BASIS FOR SEISMIC PROVISIONS

OF UCRL-15910

Prepared by:

Robert P. Kennedy
RPK Structural Mechanics Consulting
and
Stephen A. Short
EQE Engineering Consultants

Prepared for:

U.S. Department of Energy

September 1992 DRAFT

14.11

"Exact" Convolution

The probability, P_F, of unacceptable performances is obtained by a convolution of the seismic hazard and fragility curves. This convolution can be expressed by either:

$$P_F = -\int_0^{+\infty} \left(\frac{d\,H_{(a)}}{da} \right) P_{F/a}\, da \qquad 5a$$

oi

$$P_F = \int_0^{+\infty} H(a) \left(\frac{dP_{F/a}}{da} \right) da \qquad 5b$$

where $P_{F/a}$ is the conditional probability of failure given the ground motion level "a" which is defined by the SSC fragility curve.

where $H_{(a)}$ is the annual frequency of exceedance of ground motion level "a,"

- Solve by Numerical Integration

Approximate Convolution

Figure 1 presents two representative probabilistic seismic hazard curves expressed in terms of mean annual probability of exceedance versus peak ground acceleration. Curve A represents a hazard estimate for a western higher seismicity site. Curve B represents a typical hazard estimate for an eastern lower seismicity site.

Over any ten-fold difference in exceedance probabilities, such hazard curves may be approximated by:

$$H_{(a)} = K_1 a^{-k_H} \qquad (3)$$

Defining H_D as the annual frequency of exceedance of the DBE ground motion level, from Equation (3):

$$K_1 = H_D \, [DBE]^{K_H} \qquad 5g$$

$$K_H = \frac{1}{\log_{10}(A_R)} \qquad (4)$$

in which A_R is the ratio of ground motions corresponding to a ten-fold reduction in exceedance probability.

DBE = Reference Ground Motion Level (Preferably Midway Between Median and HCLPF on Fragility Curve)

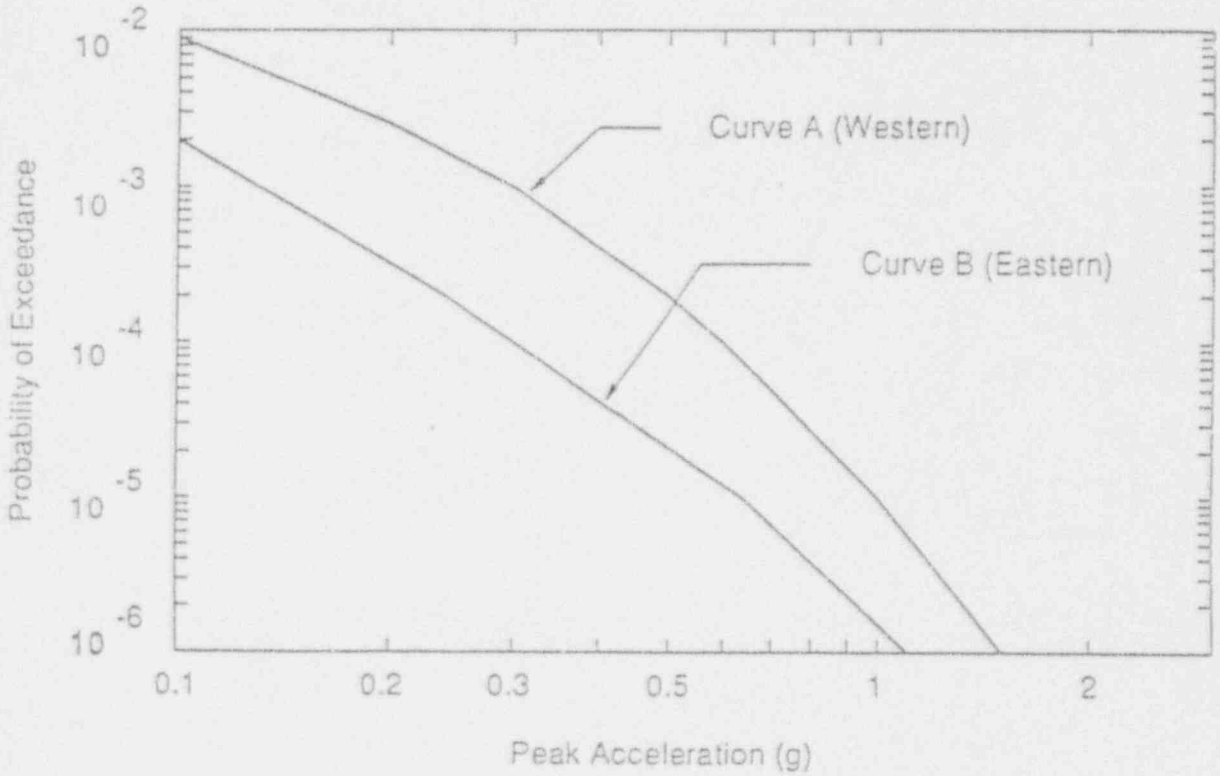


Figure 5-1: Typical Probabilistic Seismic Hazard Curves

Table 5-3

Typical Ground Motion Ratios and Hazard Slope Parameters

Hazard curve	Probability Range	A_R	K_H
A (Western)	10^{-3} to 10^{-4}	2.0	3.32
A (Western)	10^{-4} to 10^{-5}	1.67	4.49
B (Eastern)	10^{-3} to 10^{-4}	2.31	2.75
B (Eastern)	10^{-4} to 10^{-5}	2.13	3.05

Approximate Convolution (Cont.)

$$P_F = \frac{H_D \, e^{1/2(K_H \beta)^2}}{(C_{50}/DBE)^{K_H}} \quad 5$$

Equation (5) is exact so long as the fragility is lognormally distributed and the hazard curve is defined by Equation (3), (i.e., is linear-on a log-log plot).

Median Capacity

$$C_{50\%} = C_p e^{X_p \beta} \quad (10)$$

where X_p is the factor associated with the failure probability "P" for the standard normal distribution, i.e.:

P	X_p	P	X_p
1%	2.326	15%	1.037
5%	1.645	20%	0.842
10%	1.282	50%	0

- Therefore given the capacity C_p at any failure probability and the composite β one can obtain P_F.

Approximate Convolution (Cont.)

Range on β_C = 0.3 to 0.5

Corresponding Range (Median/HCLPF) = 2.0 to 3.2

Approximate Fragility

1. Estimate $HCLPF_{50}$ By EPRI CDFM Method

$$HCLPF_{50} = \frac{CDFM}{1.2}$$

2. Use Average β_C

$\beta_C = 0.4$

$C_{1\%} = HCLPF_{50}$

Median = 2.5 $HCLPF_{50}$ = 2.1 CDFM

Approximate Convolution (Cont.)

3. Set DBE at $C_{10\%}$

$$DBE = 1.5\ HCLPF_{50} = 1.25\ CDFM$$

4. Find H_D Corresponding to DBE from Hazard Curve

5. $P_F = H_D (0.6)^{K_H} e^{0.08 K_H^2}$ (Approximate)

Approximate Convolution (Cont.)

Hazard Slope Factors		
A_R	K_H	P_F/H_D
3.75	1.74	0.52
3.25	1.95	0.50
2.75	2.28	0.47
2.25	2.84	0.45
2.05	3.21	0.44
1.85	3.74	0.45
1.65	4.60	0.52
1.50	5.68	0.73

- Except for Very Steep Hazard Curves ($A_R < 1.65$)

  $P_F \approx H_D/2$

Approximate Convolution (Cont.)

Alternately if Know β_c, One Can Slightly Improve

$$DBE = HCLPF * F_D$$

$$P_f = H_D (F_H)^{K_H} e^{\alpha K_H^2}$$

Parameter	β_c 0.3	0.4	0.5
F_D	1.35	1.50	1.65
F_H	0.68	0.60	0.53
α	0.045	0.080	0.125

Approximate Convolution (Cont.)

Hazard Shape Factor		P_f/H_D		
A_R	K_H	β_c = .3	β_c = .4	β_c = .5
3.75	1.74	0.59	0.52	0.48
3.25	1.95	0.56	0.50	0.47
2.75	2.28	0.52	0.47	0.45
2.25	2.84	0.48	0.45	0.45
2.05	3.21	0.46	0.44	0.47
1.85	3.74	0.44	0.45	0.53
1.65	4.60	0.44	0.52	0.76
1.50	5.68	0.48	0.73	1.53

- Except for Steep Hazard Curves And Large β_c

$$P_f \approx H_D/2$$

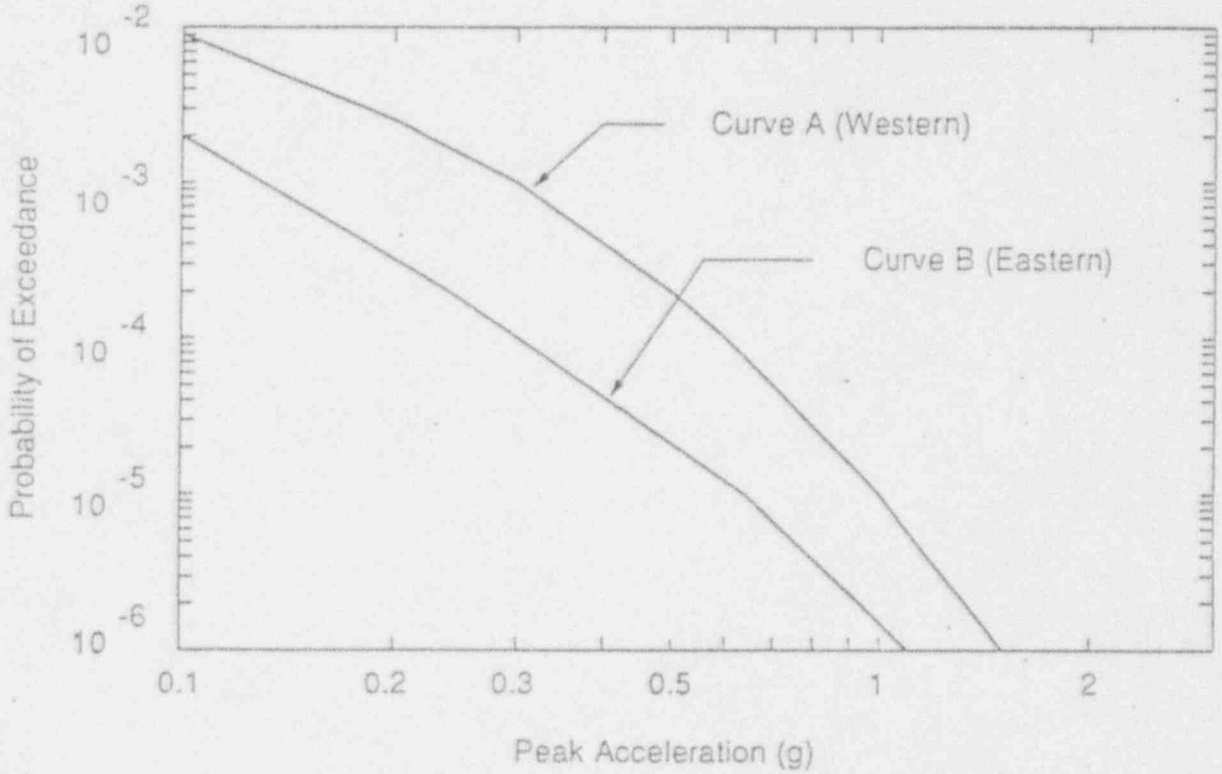


Figure 5-1: Typical Probabilistic Seismic Hazard Curves

Example

Flat Bottom Tank

Approx:

EPRI CDFM = 0.31g

DBE = 0.39g

Median = 0.68
β_C = 0.41

	Parameter	Curve A	Curve B
Approx	H_D	4.6×10^{-4}	4.6×10^{-5}
	P_F	2.3×10^{-4}	2.3×10^{-5}
"Exact"	P_F	1.6×10^{-4}	1.7×10^{-5}

- Slight Conservatism is Introduced Because Actual Hazard Curves Are Concave Downward and Not Linear and Because 0.5 Factor is Conservative

Example

ARD Relay In Cabinet

Approx:

EPRI CDFM = 0.26g

DBE = 1.25(0.26) = 0.32g

Median A = 0.81g
β_C = 0.65

	Parameter	Curve A	Curve B
Approx	H_D	8.3×10^{-4}	8.3×10^{-5}
	P_F	4.1×10^{-4}	4.1×10^{-5}
"Exact"	P_F	2.4×10^{-4}	3.2×10^{-5}

- Even With Extremely Large β_C, Approximate P_F is Less Than a Factor of Two Too Large

Example High Variability Case

Median $= 0.8g$
$\beta_C = 0.5$
$HCLPF_{50} = 0.25g$

Approx: $DBE = 1.5\ HCLPF_{50} = 0.38g$

	Parameter	Curve A	Curve B
Approx	H_D	5.0×10^{-4}	5.0×10^{-5}
	P_F	2.5×10^{-4}	2.5×10^{-5}
"Exact"	P_F	1.4×10^{-4}	1.5×10^{-5}

- Additional Conservatism Because of High β_C, But Still Within Factor of Two

Example Low Variability Case

Median $= 0.5g$

$\beta_C = 0.3$

$HCLPF_{50} = 0.25g$

Approx: $DBE = 1.5\ HCLPF_{50} = 0.38g$

	Parameter	Curve A	Curve B
Approx	H_D	5.0×10^{-4}	5.0×10^{-5}
	P_F	2.5×10^{-4}	2.5×10^{-5}
"Exact"	P_F	3.0×10^{-4}	3.3×10^{-5}

- Slightly Unconservative Because of Low β_C
- Failure Probabilities Differ By Only a Factor of Two for β_C from 0.3 to 0.5

Conclusions

To:

1. Approximately Estimate Mean Seismic Core Damage Risk
2. Determine Dominate Contributions to Seismic Risk

Can Use Approximate Approach:

$$\text{Median} = 2.1\ \text{CDFM}$$

$$\text{HCLPF}_{50} = \text{CDFM}/1.2$$

$$\beta_C = 0.4$$

$$\text{DBE} = 1.5\ \text{HCLPF}_{50} \text{ for } H_D$$

$$P_F = 0.5\ H_D$$

Suggested Simplified Seismic PRA Approach for Seismic IPE

1. Set Screening Limit at NRC Defined RLE

2. Screen Out All Stronger Components Using EPRI NP-6041-SL Screening Tables and Walkdown

3. Add A Surrogate Fragility Element to Replace All Screened Out Components

4. Compute EPRI CDFM Capacities for All Non-Screened Components

5. Obtain Approximate Fragility Curves from:

   Median = 2.1 CDFM $\beta_C = 0.4$

6. Use Approximate Fragility Curves in Systems Analyses to Define Approximate Seismic Risk and Dominant Contributors

7. For About 5 Components Which Dominate Seismic Risk Generate Accurate Fragilities and Repeat Step # 6.

Session K14

Suggested Simplifications

Reference Material