

**RIC 2006
Session W4F
Current Seismic Issues & Associated Research
March 8, 2006**

Performance-Goal Based Approach for Establishing the SSE Design Response Spectrum for Future Nuclear Power Plants

Robert P. Kennedy

**RPK Structural Mechanics Consulting
28625 Mountain Meadow Road, Escondido, CA 92026
(760)751-3510 • (760) 751-3537 (Fax)
email: bob@rpkstruct.com**

Purpose of Talk

- Outline a Practical Approach for Establishing a Performance-Goal Based SSE Design Response Spectrum
- Stimulate Interest in Further Development of Performance-Goal Based Seismic Design Criteria

Issues Which Must Be Addressed In Order to Develop a Performance-Goal Based SSE Design Response Spectrum

1. What Target Annual Probability of Seismic Induced Unacceptable Performance is Acceptable?
 - Policy Maker Decision
 - Can Be Based on Existing Precedence
2. What Minimum Seismic Margin is Achieved by Seismic Design Criteria??
 - A Question of How Much Deterministic Conservatism Exists in Design Criteria
3. Given the Decisions Made Under Issues 1 and 2, How Should the SSE Design Response Spectrum be Defined?

Step #1: Establish Target Performance Goal (Ingredient of Risk Informed Seismic Design)

Performance Goals

- Both Qualitative and Quantitative Performance Goals Should Be Established

Qualitative Goals

- What Constitutes Acceptable Performance?
- Example: Avoidance of Seismic-Induced Core Damage (SCD)

Quantitative Goal

- What is a Target Acceptable Mean Annual Frequency P_{FT} of Seismic Induced Core Damage (SCDF)
- Example: SCDF $P_{FT} \leq \text{Mean } 5 \times 10^{-6}/\text{yr}$

Step # 2: Establish Acceptable Seismic Margin Goals

- Typically Seismic Margin Has been Defined in Terms of High-Confidence-Low-Probability-of-Failure (HCLPF) Capacity
- HCLPF Approximately Corresponds to 1% Conditional Probability of Unacceptable Performance Level on Composite (Mean) Fragility Curve
- An Acceptable HCLPF Capacity is Typically Established at Some Factor Greater than the Seismic Design Response Spectrum (DRS)
- Example: For ALWR Designs NRC Staff Established (SECY-93-087)
 $F_p = (\text{HCLPF}/\text{DRS}) \geq 1.67$ for Seismic Core Damage

- Step #3: Establish Seismic Hazard Exceedance Frequency H at Which Uniform Hazard Response Spectrum UHRS Is To Be Defined

$$H = R_p * P_{FT}$$

R_p = Probability Ratio

Preferably: $2 \leq R_p \leq 20$

- Example:

Selected: $R_p = 10$

Result: $H = \text{Mean } 5 \times 10^{-5}/\text{yr}$ for $P_{FT} = \text{Mean } 5 \times 10^{-6}/\text{yr}$

- Selection of R_p is Fairly Arbitrary Since Accounted for in Step #4

STEP #4: Define Design-Basis Earthquake Response Spectrum (DRS)

$$\text{DRS} = \text{DF} * \text{UHRS}$$

DF = Design Factor

DF Function of:

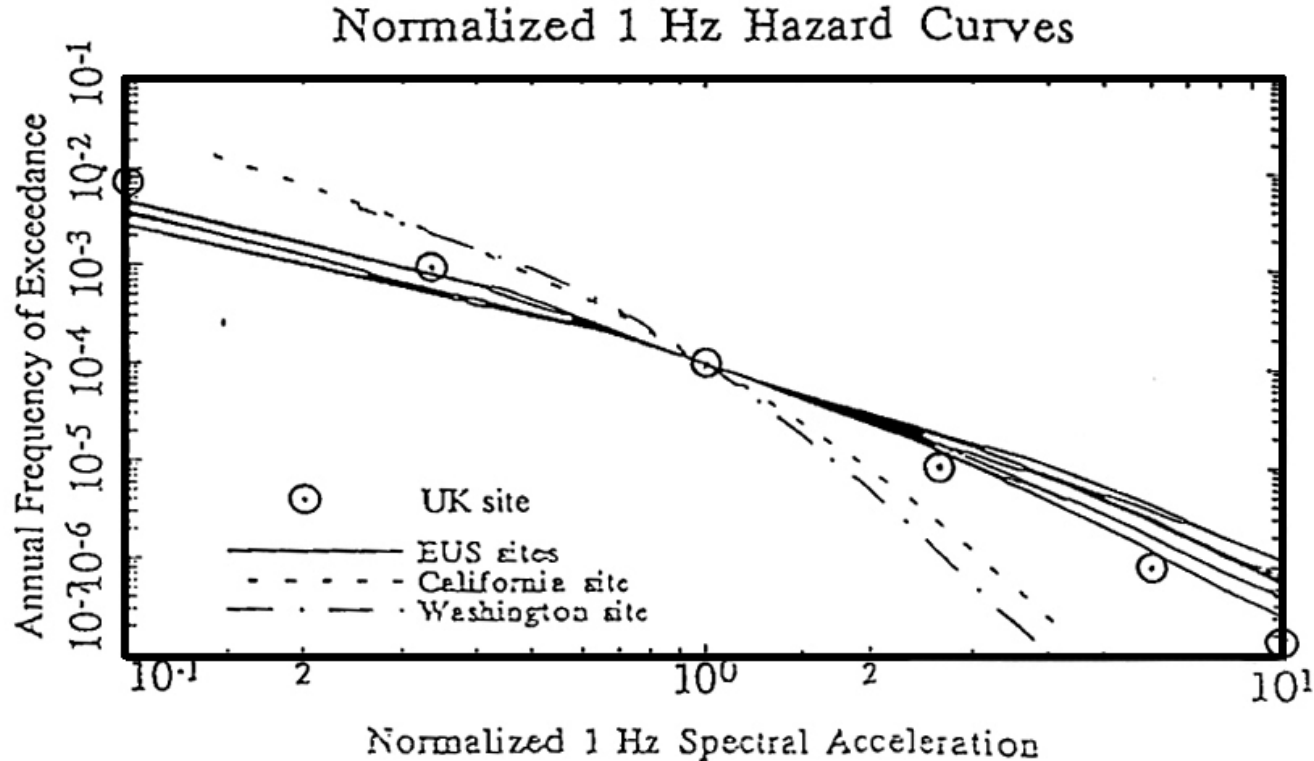
Probability Ratio R_p Defined in Step #3

Seismic Margin Factor F_p Defined in Step #2

Hazard Curve Slope Ratio A_R

A_R = Ratio of Ground Motions Corresponding to Ten-Fold Reduction in Exceedance Frequency

Seismic Hazard Curves Normalized By the Spectral Acceleration Value Corresponding to a 10^{-4} Annual Probability



STEP #4 (cont.):

Example:

$$\text{For } R_P = (H/P_{FT}) = 10.0$$

$$F_P = 1.67$$

$$DF = \text{Maximum } (DF_1, DF_2)$$

$$DF_1 = 0.241 + 0.225 A_R \geq 0.60$$

$$DF_2 = 0.375 A_R^{0.9}$$

For $H_D = \text{Mean } 5 \times 10^{-5}$

Calif. Site: $A_R = 1.5$ to 2.25

EUS Site: $A_R = 2.25$ to 4.0

**Design Factors DF For Various
Seismic Hazard Slope Factors A_R**

| A_R | DF |
|-------|------|
| 1.5 | 0.60 |
| 1.75 | 0.64 |
| 2 | 0.70 |
| 2.25 | 0.78 |
| 2.5 | 0.86 |
| 2.75 | 0.93 |
| 3 | 1.01 |
| 3.25 | 1.08 |
| 3.5 | 1.16 |
| 3.75 | 1.23 |

| A_R | DF |
|-------|------|
| 4 | 1.31 |
| 4.25 | 1.38 |
| 4.5 | 1.45 |
| 4.75 | 1.52 |
| 5 | 1.60 |

Purpose of Talk

- Outline a Practical Approach for Establishing a Performance-Goal Based SSE Design Response Spectrum
- Stimulate Interest in Further Development of Performance-Goal Based Seismic Design Criteria