NRC Regulations for Seismic Analysis and Design Applied to San Onofre Nuclear Generating Station

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Overview

1. NRC History and Overview
2. Regulations for Seismic Hazards
3. San Onofre Geologic Siting Criteria and Seismic Design
4. NRC Post-Fukushima Actions

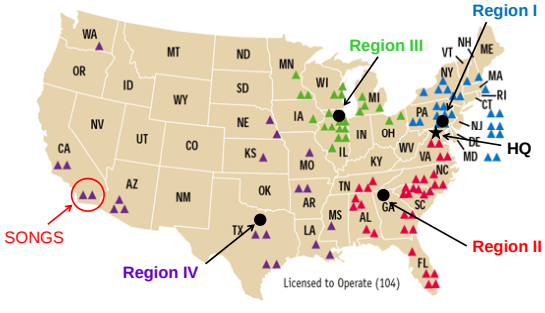
1. NRC History and Overview

NRC History

- Atomic Energy Commission
  - Atomic Energy Act of 1946
- Nuclear Regulatory Commission
  - Energy Reorganization Act of 1974

NRC.gov

Power Plant and Regional Office Locations



NRC.gov

How we Regulate

NRC.gov

2. Regulations for Seismic Design

Applicable Regulations (pre-1997)

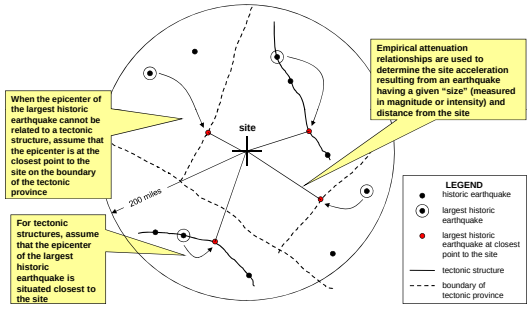
- **10 Code of Federal Regulations 100 Appendix A** Seismic and Geologic Siting Criteria for Nuclear Power Plants
  - Required geologic and seismic investigations
  - Procedures for determining design basis ground motions
- **10 Code of Federal Regulations 50 Appendix A Criterion 2** Design Bases for Protection Against Natural Phenomena
  - Structures, systems, and components shall be designed to withstand the effects of natural phenomena without loss of capability to perform their safety function

Applicable Regulations (pre-1997)

Design Bases Earthquakes (ground motions)

1. Safe Shutdown Earthquake (SSE)
   - based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology
2. Operating Basis Earthquake (OBE)
   - could reasonably be expected to affect the plant site during the operating life of the plant

Determination of the Safe Shutdown Earthquake

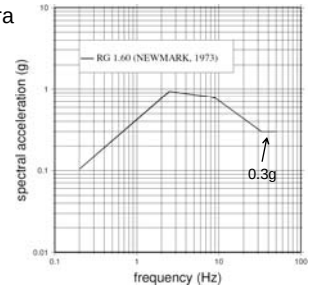


Regulatory Guidance

Regulatory Guide 1.60 (1973)

Design Response Spectra for Seismic Design of Nuclear Power Plants

- Newmark method
- 14 strong motion recordings
- Anchored to SSE acceleration



Changes to Regulations

- In the 80's probabilistic seismic hazard analysis began replacing deterministic approach
- NRC Commission Policy Statement on Severe Accidents in 1985 recognized valuable insights from probabilistic risk assessment (PRAs)
- Individual Plant Examination for External Events (IPEEE) program undertaken in the 90s

Applicable Regulations (post-1997)

- **10 CFR 100.23** Geologic and Seismic Siting Criteria
- **10 CFR 50 Appendix S** Earthquake Engineering Criteria for Nuclear Power Plants
  - uncertainties must be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis

Reassessment of Existing Plants

- When new hazard significant information comes available, the possible impact to safety of existing plants is reviewed by NRC staff
- Generic Issue program is the current program for assessment of new information

3. San Onofre Geologic Siting Criteria and Seismic Design

San Onofre Nuclear Generating Station (SONGS)

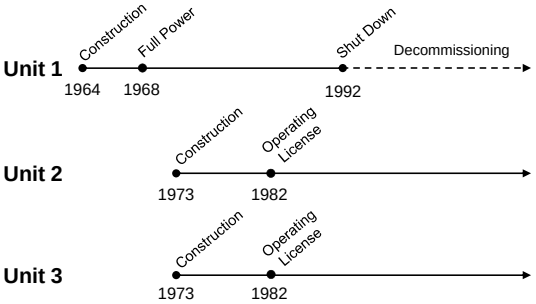
SCE

SONGS Basics

- **Operator:** Southern California Edison
- **Type:** Pressurized Water Reactor
- **Design:** Combustion Engineering
- **Architect:** Bechtel Power Corporation
- **Power:** 2200 Mw

SCE

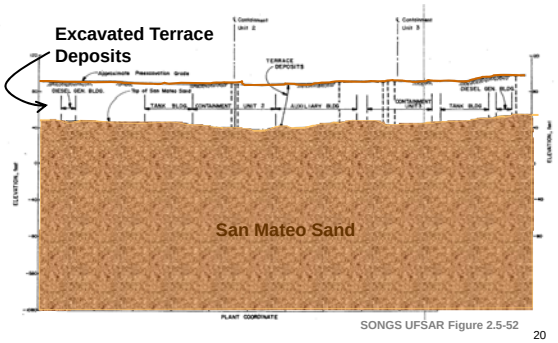
SONGS Timeline



Final Safety Analysis Report (FSAR)

- The principal document upon which the NRC bases its safety evaluation supporting the issuance of a license
- Describes the facility
- Presents the design bases and the limits on plant operation
- Provides a safety analysis of the structures, systems and components

Properties of Materials Underlying Site



SONGS UFSAR Figure 2.5-52

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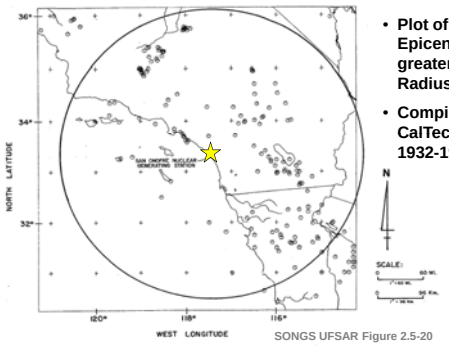
SONGS Past Earthquakes



- **Plot of Instrumental Epicenters M5.0 and greater, 200-mile Radius**
- **Compiled from CalTech Catalog, 1932-1980**

SONGS UFSAR Figure 2.5-20

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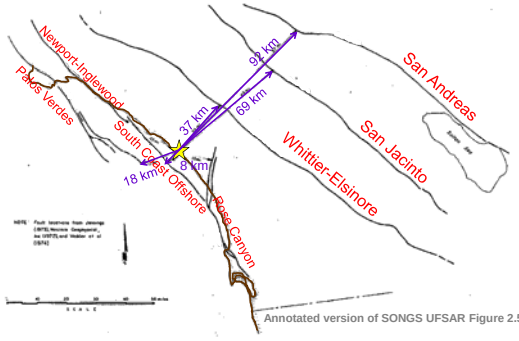
SONGS Significant Faults



Annotated version of SONGS UFSAR Figure 2.5-26

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SONGS Significant Faults

Fault	Length (km)	Nearest Approach to Site (km)	Largest Historical Magnitude	Maximum Theoretical Magnitude	Maximum Site Bedrock Acceleration (g)
San Andreas	965	92	8+	8+	0.2
San Jacinto	272	69	6.8	8	0.27
Whittier-Elsinore	233	37	5.1	7.75	0.32
Hypothesized Zone of Deformation	240	8	6.3*	7	SSE = 0.67 OBE = 0.33
Palos Verdes	96	18	None	7	0.45

Simplified version of SONGS UFSAR Table 2.5-9

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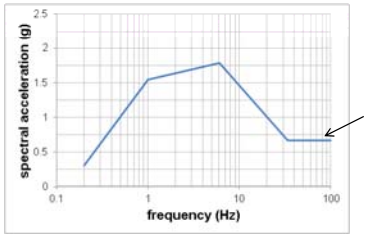
SONGS Design Response Spectra

- Safe Shutdown Earthquake (SSE)
- Horizontal



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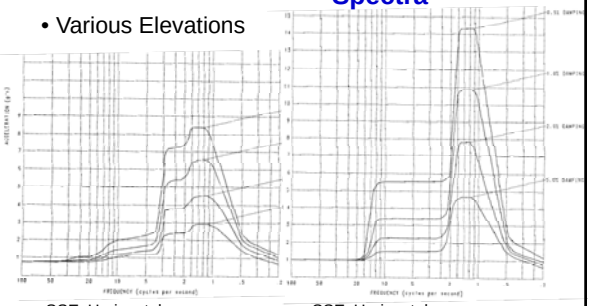
SONGS Floor Response Spectra

- Various Elevations



SSE, Horizontal, Containment Elev. 27' -7"

SSE, Horizontal, Containment Elev. 70' -3"

SONGS UFSAR Figures 37A-02, 37A-06

SONGS Damping Ratios

- (per Regulatory Guide 1.61)

DAMPING RATIOS USED IN ANALYSIS OF CATEGORY I STRUCTURES, SYSTEMS, AND COMPONENTS

Item	Maximum Damping Ratio (Percent of Critical)	
	Operational Basis Earthquake	Design Basis Earthquake
Equipment and large diameter piping systems, pipe diameter greater than 12 inches	2	3
Small diameter piping systems, diameter less than or equal to 12 inches	1	2
Welded steel structures	2	4
Bolted steel structures	4	7
Prestressed concrete structures	2	5
Reinforced concrete structures	4	7

SONGS UFSAR Table 3.7-22

SONGS Seismic Design Classification

Seismic Category I

Those structures, components, and systems designed to remain functional if a safe shutdown earthquake ground motion occurs

Seismic Category II

Those structures, components, and systems whose limited damage could interrupt generation of power.

Seismic Category III

Those structures, components, and systems whose failure could inconvenience normal plant operation

SONGS UFSAR Section 3.2

SONGS Design Load Combinations

Example: containment

Operating Conditions

$D + L + T_o + F$

Accident Conditions

$D + F + T_A + H_A + R + \mathbf{E'}$

D = dead load
L = live load
T_o = thermal load
F = prestress load
T_A = abnormal thermal loads
H_A = abnormal pipe expansion
R = pipe rupture and miscellaneous missile loads
E' = design basis earthquake load

SONGS UFSAR Section 3.8

Seismic Qualification of Equipment

Demonstrates equipment will function during and after an earthquake

Testing/Analysis

- Shake Tables
- Simulates inservice conditions
- Mathematical modeling to simulate operating capability

Seismic Instrumentation

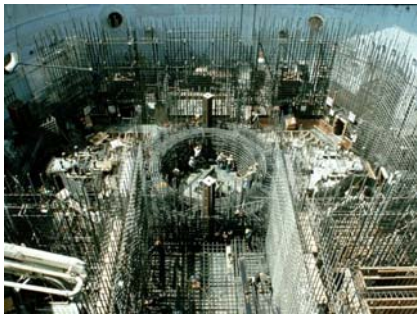
Seismic Trip

Setpoint: 0.48g

2 out of 4 logic

Yee, SCE

Pictures



Yee, SCE

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Pictures

Hale, NRC

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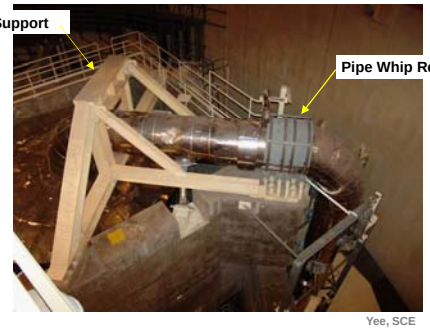
Pictures



Yee, SCE

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4. NRC Post-Fukushima Actions

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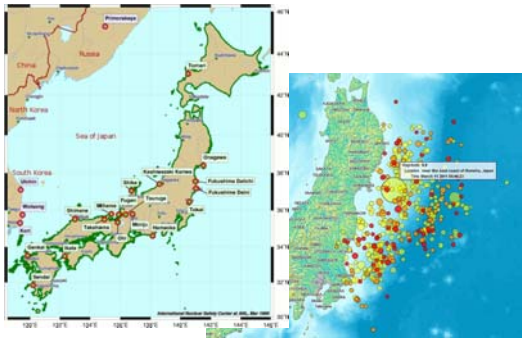
Fukushima Dai-ichi Accident



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Fukushima Dai-ichi Accident

March 11, 2011 - Great Tohoku Earthquake/tsunami

- M9, 45 feet waves; 6 nuclear power reactors extensively damaged

July 12, 2011 – Task force issued report

- No imminent danger to continued operations in U.S.
- 12 Recommendations to enhance safety and emergency preparedness

1.
2. #2. Reevaluate seismic and flooding hazard under present-day methodology and guidance
3.
4.
5.
6.

NRC

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NRC Actions

March 12, 2012 – 50.54 (f) Letters Issued

- •First regulatory requirements for 104 nuclear power plants
- •Mandatory response to five attachments

Recommendation 2 : ***Reevaluate and upgrade design-basis seismic and flooding protections of Structures, Systems, and Components***

- ❑ 2.1 Hazard Evaluation
- ❑ 2.2 Update every 10 years
- ❑ 2.3 Walkdowns

NRC Actions

Recommendation 2.1 Hazard Evaluation: Seismic

Perform a reevaluation of seismic hazards at their site using present-day requirements

- ❑ Recommends Senior Seismic Hazard Analysis Committee (SSHAC) process
- ❑ Ground Motion Response Spectrum using a probabilistic approach

RG 1.208

•Compare reevaluated seismic hazard and current design basis and results will be:
- •No further risk
- •Seismic risk assessment
  - •Probabilistic risk assessment (SPRA)
  - •Margin assessment (SMA)

Staff approved methods

NRC Actions

Recommendation 2.1 Hazard Evaluation: Seismic

SSHAC Objective:

Create reproducible, stable estimates of probabilistic seismic hazard at a site (greater regulatory assurance)

- ❑ Evaluation – considering the data, models, and methods of the larger technical community
- ❑ Integration – building models that represent the center, body, and range of technically defensible interpretations

NRC Actions

Recommendation 2.1 Hazard Evaluation: Seismic

SSHAC - Series of 3 workshops

- ❑***1st Significant Issues and Available Data***
- ❑***2nd Alternative Interpretations***
- ❑***3rd Feedback***
- ❑***Peer Review***

NRC Actions

Recommendation 2.3 Walkdowns: Seismic

Identify and address vulnerabilities until longer term actions completed

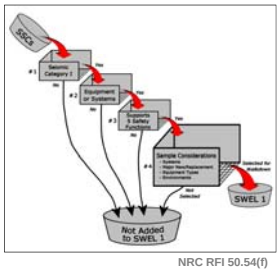
Focus on degraded, nonconforming, or unanalyzed conditions

- •Electric Power Research Institute (EPRI) guidance
- •Reports due in 180 days (Nov 2012)
- •Temporary Instruction required Resident Inspectors to accompany licensee team and conduct independent review

NRC Actions

Recommendation 2.3 Walkdowns: Seismic

Key Personnel & Seismic Walkdown Equipment List



NRC RFI 50.54(f)

NRC Actions

Recommendation 2.3 Walkdowns: Seismic

Potential Issues:

1. Go through licensing basis evaluation
2. If not easily dispositioned, added to Corrective Action Program
3. All open items at time of reporting go into CAP

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Thank You

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6. U.S. NRC, "Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies," NUREG-2117, Rev. 1, ADAMS Accession No. ML12118A445, Washington, DC, 2012.
7. U.S. NRC, "Request for Information Pursuant to Title 10 of the *Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the* Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," ADAMS Accession No. ML12056A046, Washington, DC, 2012.