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PEER Annual Meeting 2011

**Seismic regulations for NPPs in the US:
Past, Present and Future**

- 1954 Atomic Energy Commission (AEC)
- Energy Reorganization Act of 1974
 - Department of Energy
 - Nuclear weapons, promotion of nuclear power, care of low-level radioactive waste, and other energy-related work
 - Nuclear Regulatory Commission
 - Regulation of the civilian uses of nuclear materials including power production, medical and other uses
- Nuclear Non-Proliferation Act of 1978
 - Limits the spread of nuclear weapons. Established criteria governing U.S. nuclear exports licensed by the NRC and strengthened international safeguards system

History

- 1950s to 1970s US built plants generating 16% of total power (104 currently)
- 1979 Three Mile Island Accident
- 1986 Chernobyl Nuclear Disaster
- 450+ nuclear plants in 30 countries
- Changes in energy policy
 - New financial incentives in US energy policy
 - Certified design concept becomes law
 - Time limits on NRC response
- NRC now has 20+ applications in-house
 - COL applications
 - Certified design applications

History

- Many types of Regulatory Documents
 - Code of Federal Regulations
 - Regulatory Guidance
 - NUREG-Series Documents
 - Standard Review Plan (NUREG 0-800)
 - Plant Operating Licenses
- Hearings and proceedings
- Oversight committees
- Public Meetings
- Open public process

US Regulation

- The earliest seismic hazard and design guidance came from the AEC and evolved over the early years.
- Early seismic hazard assessments for the DBE were deterministic with standard spectra (Newmark spectrum and the RG1.60 spectrum) tied to a PGA based on past earthquakes in the region.
- Design was conservative with for facilities to remain in the linear range.

Early Seismic Design

- In 1971 the NRC established **General Design Criteria (GDC 2)**, which required that SSCs important to safety be designed to withstand the effects of natural phenomena with “appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding region with sufficient margin for the limited accuracy and quantity of the historical data and the period of time in which the data have been accumulated” (Appendix A to 10 CFR Part 50)

Early Seismic Design

- In 1973, Appendix A, “Seismic and Geologic Siting Criteria for NPPs” to 10 CFR Part 100 was established to provide detailed criteria to evaluate the suitability of proposed sites and the suitability of the plant design basis established in consideration of seismic and geological characteristics.

Early Seismic Design

- As a result of the evolution of hazard and design criteria, in 1977, the NRC initiated the Systematic Evaluation Program (SEP) to review the designs of older operating NPPs to reconfirm and document their safety.
- This one time program evaluated plants, required changes as necessary, and documented the activities for each plant.

Early Seismic Design REVIEW

- Equipment qualification also evolved.
- In 1980 the NRC established Unresolved Safety Issue A-46, “Seismic Qualification of Mechanical & Electrical Equipment in Operating Power Plants,” to reassess older NPPs
- A-46 developed seismic qualification methods for safety-related equipment in existing plants.
- Led to Generic Letter 87-02 to Licensees
- NRC current RG1.100, based partly on IEEE 344-2004 and ASME QME-1-2007

Qualification of Equipment

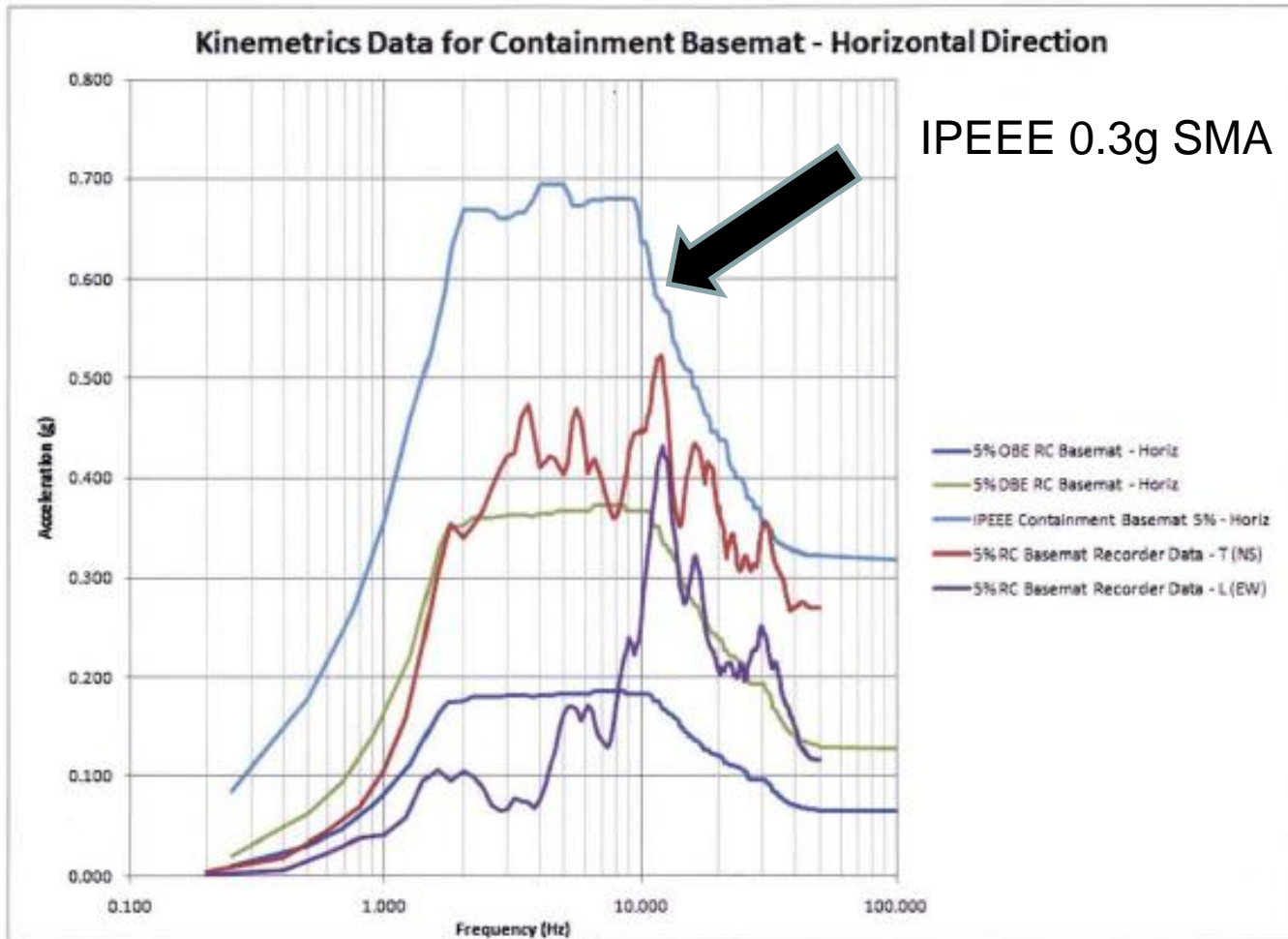
- NRC continued to develop new techniques
 - Seismic Probabilistic Risk Assessment (SPRA)
 - Probabilistic Seismic Hazard Analysis (PSHA)
- In 1991, the NRC established the Individual Plant Examination of External Events (IPEEE) program, with a goal of identifying plant-specific vulnerabilities to severe accidents, if any, and to report the results with any licensee-proposed improvements and corrective actions to the NRC.

IPEEE

- The IPEEE identified and addressed a number of plant vulnerabilities and improved walk down techniques.
- Licensees had the option to use one of 3 techniques, and most used the Seismic Margins Assessment. However, approximately a third of the plants were assessed with Seismic PRA methods, making it the first wide-scale use of SPRA.

IPEEE

Comparison of Kinematics Data – Horizontal Direction



Provided to the NRC in a September 2011 public meeting.
NRC staff has not accepted all the data as accurate at this time.

In 1996, the NRC issued new laws to complete the current basis for hazard:

10 CFR Part 50 Appendix S defines **SSE** as “**Safe-shutdown earthquake ground motion** is the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional” (performance-based requirement replacing the deterministic DBE)

10 CFR Part 50 also states that “*The nuclear power plant must be designed so that, if the Safe Shutdown Earthquake Ground Motion occurs, certain structures, systems, and components will remain functional and within **applicable stress, strain, and deformation limits.***”

US Code of Federal Regulations

10 CFR Part 100.23 “Geologic and Seismic Siting Criteria” requires that the applicant determine the SSE and its **uncertainty**, the potential for surface tectonic and nontectonic **deformations**.

10 CFR Part 50 Appendix A states “Structures, systems, and components important to safety shall be designed to withstand the effects of **natural phenomena such as earthquakes, . . . , without loss of capability to perform their safety functions**”.

US Code of Federal Regulations

- In 1997 NRC was issued a commission directive to move towards “Risk Informed” policies.
- 1997 issuance of RG 1.165, which was the first seismic hazard guide based partially on probabilistic techniques.
- 2007 NRC issued RG1.208, “A Performance-Based Approach to Define the Site-Specific Ground Motion,” based on PSHA. RG1.208 was developed for use with ASCE 43-05, *Seismic Design Criteria for SSCs in Nuclear Facilities*.
- Uses 10^{-4} to 10^{-6} ground motions. 10^{-4} for SSE.

New Regulatory Guidance

- SSC performance target risk goals
 - Frequency of the Onset of Significant Inelastic Deformation (FOSID) of 10^{-5} for individual SSCs
 - Core Damage Frequency (CDF)
 - $\sim 10^{-6}$ /yr for new plants
 - $\sim 10^{-5}$ /yr for existing plants as per draft GI-199 letter
 - Plant Level HCLPF 1.67 times the SSE
- Overall plant risk assessed through Seismic Probabilistic Risk Assessment

Risk-Informed Regulation

- In mid-2000s interest was renewed in new NPPs and the NRC received 3 Early Site Permit (ESP) applications for reactors to be co-located at existing sites.
 - North Anna, Vogtle, and Calvert Cliffs
- Based on the difference in the new PSHA data and the DBEs for the existing reactors, NRC Staff initiated Generic Issue (GI)199.

Impact of the Nuclear Renaissance

- GI-199 is an program to reevaluate seismic hazard and risk for central & eastern US NPPs
- Prior to Fukushima, the NRC performed and published an initial screening required to show that GI-199 met program criteria (risk-significant changes to multiple NPPs)
- Now GI-199 has been extended to all NPPs, as per the Draft Generic Letter issued to the public for comment. GI-199 may be extended further due to the Fukushima NTF recommendations.

Generic Issue 199

Source
Characterization →

Central and Eastern US Seismic
Source Characterization project for
Nuclear Facilities (CEUS SSC)

Ground motion
prediction equations →

Next Generation Attenuation
Relationships for the Central and
Eastern (NGA-East)

Framework for large
PSHA studies →

Recommendations for Application
of the SSHAC Guidelines

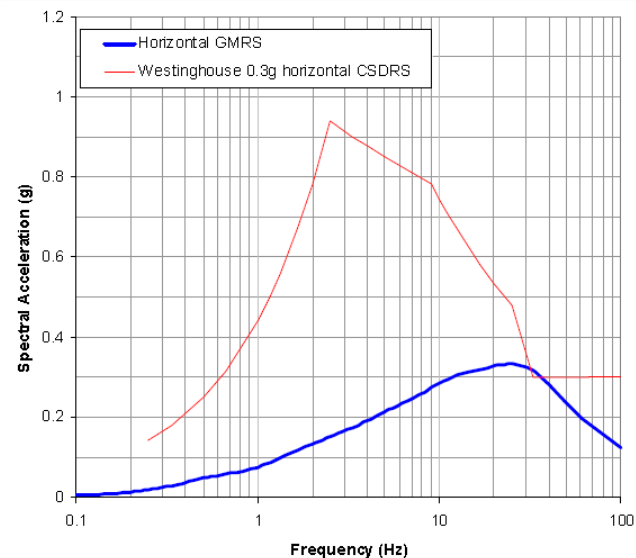
Seismic Hazard Assessment Research

- 10 CFR Part 52: Certified Design for NPPs
- Site Analysis
 - 10^{-4} annual probability ground motion (with design factors) compared to certified design
 - Geotechnical properties assessed for compliance with requirements
- Combine with other information in COL

Current US Regulation

GRMS is based on site characterization and it is determined from detailed seismic hazard studies

CSDRS is based on engineering design of a plant



- Although not specific to seismic, many other NRC programs related to defense-in-depth have improved seismic risk over the years.
 - Station Blackout (SBO) rules
 - Extreme Damage Mitigation Guidelines (EDMGs)
 - Severe Accident Mitigation Guidelines (SAMGs)
- Because these were developed at different times, and are not part of the licensing basis, these programs are each addressed separately with differing levels of enforceability.

Other NRC initiatives

**RECOMMENDATIONS FOR
ENHANCING REACTOR SAFETY
IN THE 21ST CENTURY**

THE NEAR-TERM TASK FORCE
REVIEW OF INSIGHTS FROM THE
FUKUSHIMA DAI-ICHI ACCIDENT



Fukushima
Lessons Learned
Report with
Significant
Recommendations
for changing NRC
regulations and
practices

NRC
ML111861807

- The NRC has principally deterministically-based regulations with risk assessments used for consideration of defense-in-depth for beyond-design-basis events. Plants are deterministically designed but have to show acceptable risk through a SPRA before fuel loading.
- **Recommendation 1:** Establish a logical, systematic, and coherent regulatory framework for adequate protection that appropriately balances defense-in-depth and risk considerations.

NRC NTTF Recommendations

- **Recommendation 2:** Require Licensees to reevaluate and upgrade as necessary the design-basis seismic and flooding protection of SSCs for each operating reactor
 - **2.1** Order licensees to reevaluate the seismic and flooding hazards at their sites against current NRC requirements and guidance, and if necessary update the design basis and SSCs important to safety to protect against the updated hazards (*note: the NRC already had GI-199*)

NRC NTTF Recommendations

- **2.2** Initiate rulemaking to require licensees to **confirm seismic hazards and flooding hazards every 10 years** and address any new and significant information. If necessary update the design basis for SSCs important to safety to protect against updated hazards.
- **2.3 Order Licensees to perform seismic and flood protection walkdowns** to identify & address plant-specific vulnerabilities and verify the adequacy of monitoring and maintenance for protection features...

NRC NTTF Recommendations

- **Recommendation 3:** As part of the longer term review, the NRC evaluate potential enhancements to the capability to prevent or mitigate **seismically induced fires and floods.**

If you are at all interested in the NRCs history or future, this is an essential and interesting read!

NRC NTTF Recommendations

AEC	Atomic Energy Commission
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
COL	Combined Operating License
DBE	Design Basis Earthquake
EDMG	Extreme Damage Mitigation Guideline
FOSID	Frequency of the Onset of Significant Inelastic Deformation
HCLPF	High Confidence of a Low Probability of Failure
GDC	General Design Criteria
GL	Generic Letter (to Licensees)
IEEE	Institute of Electrical and Electronics Engineers

Acronyms

NPPs	Nuclear Power Plants
NRC	Nuclear Regulatory Commission
NTTF	Near Term Task Force (on Fukushima)
PEER	Pacific Earthquake Engineering Research
PGA	Peak Ground Acceleration
QME	Qualification of Mechanical Equipment
RG	Regulatory Guide
SAMG	Severe Accident Mitigation Guideline
SEP	Systematic Evaluation Program
SSE	Safe Shutdown Earthquake
SSC	Structures, Systems and Components

Acronyms

A large, stylized graphic of an atomic symbol, consisting of a central blue sphere and three intersecting elliptical orbits in shades of blue, positioned on the left side of the slide.

Thank You

**Risk-informed seismic design of
US Nuclear Power Plants**

Mineral, Virginia M 5.8 Eq., Base Mat

