Preclosure Safety Analysis for Seismically Initiated Event Sequences

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Abstract

This paper describes a methodology to determine probabilities of occurrence of seismically initiated event sequences, considering event occurrence probabilities and performance of structures, systems, and components (SSCs). The methodology can be used to assess safety of the preclosure facility for the seismic hazard at the proposed geologic repository at Yucca Mountain, Nevada, and to demonstrate compliance with the risk-informed, performance-based regulations in the U.S. Code of Federal Regulations, Title 10, Part 63. The probability of occurrence of an event sequence leading to an SSC failure is determined by convolution of the seismic hazard curve with the conditional failure probabilities (i.e., fragility) of the SSCs. The methodology is illustrated using examples of potential event sequences. The methodology described in the paper shows how the safety of a facility during a seismic event can be determined using the performance-based regulations. The scope of the paper is limited to estimating the probabilities of occurrence of potential event sequences leading to failure of SSCs and potential release of radioactivity; it does not discuss dose or risk estimates.

Mission of the U.S. Nuclear Regulatory Commission (NRC)

The NRC's mission is to regulate the Nation's civilian use of byproduct, source, and special nuclear materials to ensure adequate protection of public health and safety, to promote the common defense and security, and to protect the environment.

The NRC's regulatory mission covers three main areas:

Reactors - Commercial reactors for generating electric power and research and test reactors used for research, testing, and training

Materials - Uses of nuclear materials in medical, industrial, and academic settings and facilities that produce nuclear fuel

Waste - Transportation, storage, and disposal of nuclear materials and waste, and decommissioning of nuclear facilities from service

How the Safety Goal is Achieved

The NRC achieves its safety goal by licensing individuals and organizations to use radioactive materials for beneficial civilian purposes and then ensuring that the performance of these licensees is at or above acceptable safety levels. In particular, we maintain vigilance over safety performance through ongoing licensing reviews and inspections, and expanded oversight. We also use enforcement actions for significant deficiencies, including issuing orders for corrective action, issuing shutdown orders, imposing civil penalties and/or criminal prosecution, or, when appropriate, suspending or revoking a license.

Regulations are issued under the U.S. Code of Federal Regulations (CFR), Title 10, Chapter 1, and address nuclear safety throughout the lifetime of a facility.

Strategies for Nuclear Safety

1. Leak-tight Barriers (natural and engineered) between the radioactive source and the public
2. Concept of defense in depth

Methods to Ensure Performance of Engineered Leak-tight Barriers

1. Design-based deterministic approach, considering maximum demands on the structures, systems, and components (SSCs) forming the engineered barriers, and ensuring that the capacities using the consensus codes and standards exceed the demands
2. Risk-informed performance-based approach, requiring a license applicant to meet dose performance requirements, while providing flexibility in designing the facility.

Regulations for the proposed geologic repository at Yucca Mountain, NV

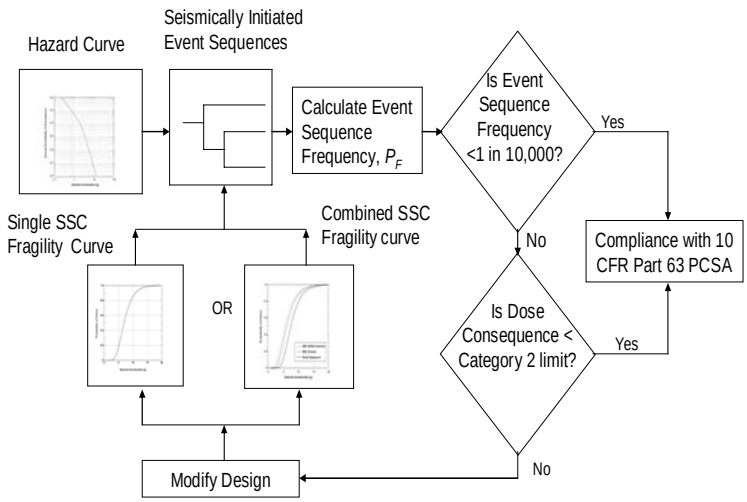
10 CFR Part 63 regulations, governing the licensing of the proposed repository, are risk-informed performance-based.

Performance of SSCs

Discussion in this paper is limited to a methodology for demonstrating the performance of SSCs important-to-safety (ITS) in the preclosure safety analysis during a seismic event, for compliance with 10 CFR Part 63. The scope of the paper is limited to estimating the probabilities of occurrence of potential event sequences leading to failure of SSCs and potential release of radioactivity; it does not discuss dose or risk estimates.

The methodology, however, is general, and can be applied to evaluate the performance of engineered barriers during the longer time frames of the post-closure period of the geologic repository, if SSC conditional failure probabilities (i.e., fragility curves) are developed, based on considering the effects of the longer time periods on material capacities.

Methodology for Evaluation of Seismically initiated Event Sequences



Description of the Methodology

1. Seismically initiated event sequence probability of occurrence is determined by convolving the mean fragility curves of the SSCs with the seismic hazard curve.
2. Event sequence probability of occurrence (PO) is then compared with the regulatory threshold of a Category 2 event sequence PO of 1 in 10,000 during the pre-closure period. If the PO is less than the regulatory threshold, compliance with Part 63 is demonstrated. If PO is more than the regulatory threshold, either dose consequence can be calculated to meet the dose performance requirements, or designs may be modified to comply with Part 63.

Conclusions

Performance of SSCs relied on to ensure nuclear safety during a seismic event can be determined using a methodology, as described in this paper, to demonstrate compliance with the risk-informed performance-based regulations of Part 63. The methodology is based on the convolution of the seismic hazard curve and the SSC conditional failure probabilities or fragility curves.