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NRC Staff Review of TerraPower Topical Report: "Plume Exposure Pathway Emergency Planning Zone Sizing Methodology"

Office of Nuclear Reactor Regulation (NRR)
Division of Advanced Reactors and Non-Power Production and Utilization Facilities (DANU)

Office of Nuclear Security and Incident Response (NSIR)
Division of Preparedness and Response (DPR)

ACRS Full Committee Meeting
November 7, 2024

Review Staff

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Agenda

- Topical report (TR) purpose and review strategy
- Safety evaluation (SE) overview
  - Focus on updates since ACRS subcommittee meeting
- Conclusions

Revised Draft SE

Following discussions during the September 19, 2024, ACRS Subcommittee meeting, staff made changes to the draft SE

- Reflected TR revision 3 to clarify the treatment of uncertainties in non-seismic sequence screening, including cliff-edge effects
- Imposed a new limitation and condition related to the selection of the seismic release scenario
- Updated limitation and condition 2 regarding hazards
- Made editorial changes to provide further clarity to SE

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TR Purpose and Review Strategy

- Purpose of TR
  - Provide methodology and criteria that will be used to establish the site-specific plume exposure pathway (PEP) Emergency Planning Zone (EPZ) size for the Natrium reactor
  - Risk-informed approach to determine EPZ size by meeting criteria in 10 CFR 50.33(g)(2)
- Review strategy
  - Review consistency with the technical basis for the alternative EP framework in 10 CFR 50.160 and conformance with guidance on PEP EPZ sizing (RG 1.242)
  - Assess acceptability of the risk-informed approach and interaction with overall Natrium licensing approach using the Licensing Modernization Project methodology

Note - 10 CFR 50.160 was issued November 16, 2023. TR Revision 1 made changes to address the proposed final rule and guidance.

TR EPZ Sizing Methodology Steps Overview

- Accident screening to identify spectrum of accidents
  - Compile release sequences from the probabilistic risk assessment (PRA) for all internal and external initiators
  - Perform screening of non-seismic release sequences based on frequency, including uncertainty
  - Perform screening of seismic release sequences with a unique set of selection criteria, including uncertainty
- Radiological consequence analysis
  - Collect meteorological data and incorporate into the radiological consequence analysis
  - Perform source term and radiological consequence analysis
  - Evaluate the radiological consequences against the PEP EPZ dose-related criteria to determine if changes are needed
- Determine PEP EPZ distance based on EPZ sizing criteria

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Development and Uses of PRA

- Design- and site-specific PRA will be used to identify release sequences
- The PRA will address internal and external hazards, all modes of operation, and all sources of radioactive material
  - *Updated Limitation and Condition 2: An applicant that references this TR must justify the technical acceptability of the PRAs performed for the selected hazards and modes (e.g., site-specific scoping level PRA). Prior to the initial fuel loading, PRAs supporting this methodology must include all applicable hazards and modes.*

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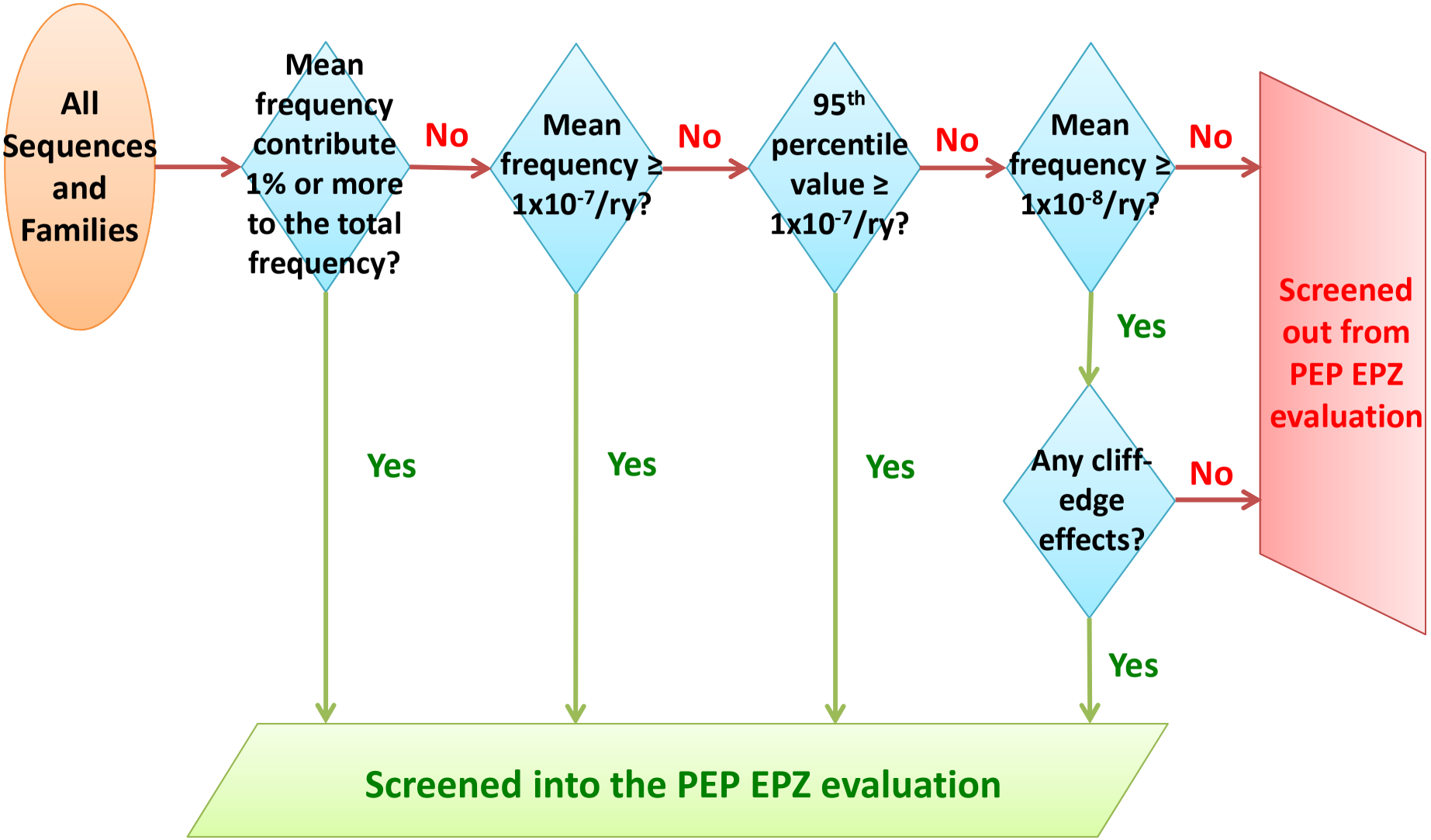
Development and Uses of PRA

- The PRA will be developed in accordance with the guidance provided in the ASME/ANS non-light water reactor (NLWR) PRA standard
- The PRA will undergo a peer review
- Key assumptions and sources of uncertainty will be assessed to determine their impacts on the calculation
- A qualitative or quantitative assessment of security events will be conducted and documented in the size calculation

Selection of Non-Seismic Release Sequences



Selection of Seismic Release Sequences

- A limiting PGA will be used to establish seismic event(s) for use in the PEP EPZ calculation at the CP stage
- The limiting PGA will be two times the ground motion response spectrum (GMRS) or a maximum of 1.0 g
- A new Limitation and Condition was established related the use of 1.0 g PGA:
  - *New Limitation and Condition 5: An applicant that references this TR will provide site-specific justification for the use of the upper bound PGA of 1.0g when exercising the methodology in TR Section 3.7, "Selection of Seismic Release Sequences."*
- The site-specific scoping level seismic PRA (SPRA) will be performed to provide additional insights

Radiological Consequence Analysis to Support EPZ Sizing

- EPZ sizing analysis uses output of methodologies in related TRs under review*
  - Radiological Source Term Methodology
  - Radiological Release Consequences Methodology
- Source terms are developed as part of safety analysis and PRA - used as input to EPZ sizing analysis
  - NRC staff will review the development of source terms as part of its review of a related license application safety analysis report, including the implementation of the related source term TR

* Information on Natrium topical report reviews available at https://www.nrc.gov/reactors/new-reactors/advanced/who-were-working-with/licensing-activities/pre-application-activities/natrium.html

Dose Estimation

- TR methodology identifies that doses are first estimated at a proposed PEP EPZ distance and compared to the three dose-based criteria
  - The PEP EPZ will be established at the furthest distance at which all three criteria are met
- Iterative process to determine PEP EPZ
  - If the result at the proposed distance is unacceptable, change the PEP EPZ size or make design changes (during design phase)

Comparison to Dose-related Criteria for Most Radiological Release Sequences

Criterion A (DBAs) and Criterion B (mean release frequency > 1×10^{-6} per reactor year (/ry))

- Compare mean 96-hour dose for event to lower end of EPA Protective Action Guide (PAG)* range (1 rem TEDE)
- Compare 95th percentile 96-hour dose for event to upper end of EPA PAG range (5 rem TEDE)

*The EPA PAG levels to recommend evacuation or sheltering of the public during the early phase of a radiological incident are 1 to 5 rem (10 to 50 mSv) projected dose over four days (2017 EPA PAG Manual)

Comparison to Dose-related Criterion for Worst-case Radiological Release Sequences

Criterion C (mean release frequency 1×10^{-7}/ry to 1×10^{-6}/ry)

- Compare to dose metric of 200 rem red marrow acute effective dose for a 24-hour exposure period
- Generate dose-distance chart mapping the dose reduction as one moves away from the EPZ
  - Analysis to ensure that the dose drops rapidly beyond the PEP EPZ boundary

Probabilistic Dose Aggregation and Treatment of Uncertainty

- Criterion C considers scenarios with lower frequency than used to determine licensing basis events with LMP
- TR Section 6.3 describes the uncertainty and sensitivity analysis methodology
  - Monte Carlo sampling on PRA event frequencies
  - Source term and consequence analysis uncertainty results are included, as determined in the related methodology TRs
  - Cliff-edge effect evaluations
    - Events with frequencies between 1×10^{-7} /ry and 1×10^{-8} /ry
    - Primary focus on single failures that would dramatically change either risk metrics or the effects of the accident sequences (timing, plant response, source terms, or end states)

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Necessity of Predetermined Prompt Protective Measures Criterion

- Radiological release timing used to identify necessity of prompt protective measures
  - Each event assessed individually to determine if timing supports necessity of prompt protective measures
  - Identified protective measures will inform emergency plan and procedures

Conclusions

The NRC staff determined that the TR, subject to the limitations and conditions, provides an approach acceptable to develop analyses to aid in the determination of a site- and design-specific PEP EPZ for the Natrium reactor.

Accordingly, the NRC staff concludes that the TR can be used in establishment of the PEP EPZ size to support emergency planning and preparedness in compliance with the regulatory requirements in 10 CFR 50.33(g) and 10 CFR 50.47(c)(2), as applicable, for prospective TerraPower Natrium reactor CP or operating license applications under 10 CFR Part 50.

Abbreviations

ANS	American Nuclear Society
ASME	American Society of Mechanical Engineers
CFR	Code of Federal Regulations
CP	construction permit
DBA	design basis accident
EP	emergency preparedness
EPA	Environmental Protection Agency
EPZ	emergency planning zone
g	gravitational acceleration
GMRS	ground motion response spectrum
L&C	limitation and condition
NLWR	non-light water reactor
PAG	protective action guide
PEP	plume exposure pathway
PGA	peak ground acceleration
PRA	probabilistic risk assessment
RG	regulatory guide
ry	reactor year
SE	safety evaluation
SPRA	seismic probabilistic risk assessment
TEDE	total effective dose equivalent
TR	topical report