ANS Working Group 54.1
Nuclear Safety Criteria and Design Process for Sodium-Cooled Reactor Nuclear Power Plants

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Codes and Standards Panel

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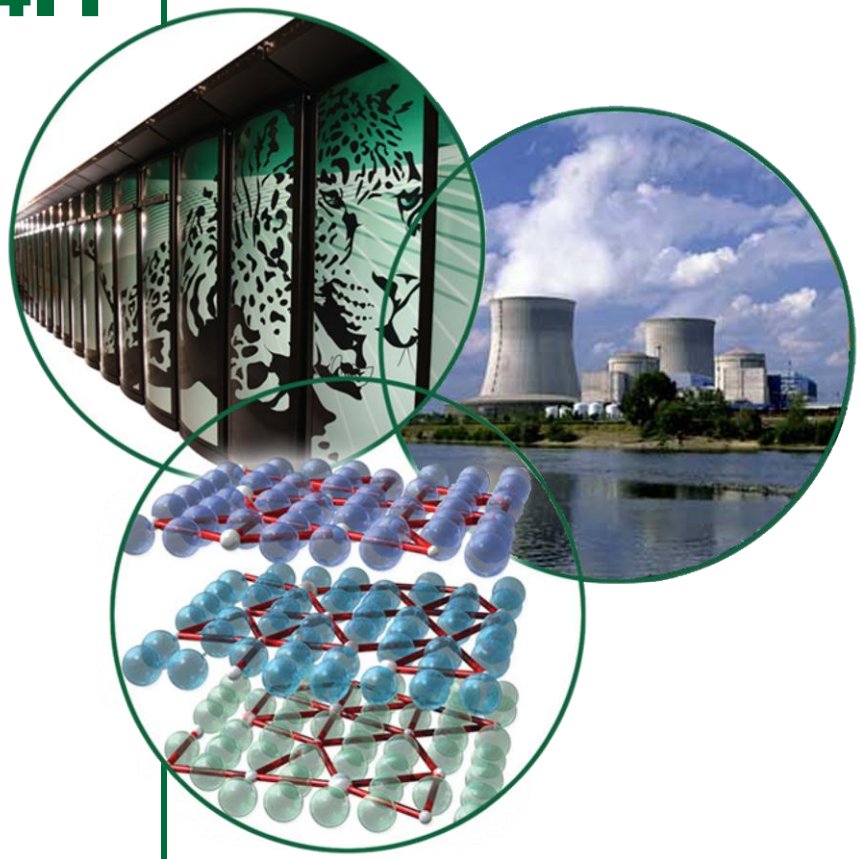

U.S. DEPARTMENT OF ENERGY

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ANS 54.1 is Viewed as A Revision of the Original ANS 54.1 Standard Withdrawn in 1999

- Original was developed in 1989 as result of the licensing actions on the PRISM and SAFR Reactors
- Purpose of the original was to provide a set of equivalent General Design Criteria (Appendix A of 10CFR50) for LMRs
- The revised 54.1 recognizes changes in the LMR technology and the use of PRA and risk informed performance-based approach to the safe design of a reactor

The Standard Defines the Safety Objectives and General Design Criteria That Can Be Used by Designers and Regulators of SFRs

- Define Criteria to be satisfied for providing assurance that SFRs are designed so that they can be operated with acceptable risk to the public and the environment
  - Applicable safety requirements
  - Industrial codes and standards
  - Professional engineering practices
  - Acceptable use of PRA information in support of design where applicable

The Standard Makes Use of Probabilistic and Deterministic Design Criteria

- Relies on a melding of probabilistic and deterministic methods
  - Recognizes designers' use of deterministic methods and incorporate margin to accommodate for the unexpected
  - Risk information can determine the amount of margin by predicting the types of off-normal operation that can occur with estimates on the impact such operation may have on the public health and environment
- The standard recognizes the need for defense-in-depth (DID)
  - No single layer of defense is relied on no matter how robust
  - Risk information may be used to determine the number of layers of defense that are needed to allow assurance of the protection of the public and environment

High Level Safety Objectives

- Accident prevention
  - AOOs no fuel damage or loss of fuel function
  - DBAs no loss of coolable core geometry
  - Core damage frequency of $\leq 10^{-5}$/year (mean value)
- Accident mitigation (required as part of DID)
  - AOOs no loss of integrity of function of barriers containing radioactive material
  - DBA, no loss of containment integrity or function
  - Large Release Frequency (LRF) $\leq 10^{-6}$/year (mean)
  - For all licensing basis events containment integrity maintained for at least 24 hours from start of accident

High Level Safety Objectives (continued)

- Risk Management
  - Identify and use viable features that reduce the internal and external challenges to the NPP and enhance safety, safety assurance, and risk manageability
    - Seismic isolator
    - Passive safety
    - Slowing accident progression
  - No single, equipment failure or human action should contribute more than 10% to overall plant risk

Eight High-Level Safety Functions Have Been Identified

- Overall plant protection
- Core heat removal
- Reactor shutdown
- Maintaining the coolant inventory
- Residual heat removal
- Containment of radioactive material
- Containment heat removal
- Preventing and mitigating energetic reactions

Overall Plant Protection

- Quality
  - Analysis
    - Codes and standards
    - Mechanistic source term
  - PRA
  - Probabilistic approach in lieu of single failure criteria
  - Allow graded QA based on risk significance
- Fire protection (including risk informed and NFPA-805)
- Sharing of SSCs
- Selection of LBE
  - Requirements for determining frequency categories for AOO, DBE, and BDBE

Overall Protection (continued)

- LBE selection using engineering judgment when PRA is judged not sufficient
- Acceptance criteria
  - AOO not fuel damage
  - DBE no core melt, containment intact
  - BDBE long time to release and maintain coolant inventory
  - Dose regulatory limits
- Safety classification of SSCs
  - Use of PRA for classification
  - Define requirements for risk informed safety classification
- EQ

Overall Protection (continued)

- Aging management
- Shutdown, fuel handling, and fuel storage
- Sodium heating systems
- Structural and equipment cooling
- Prevention of criticality
- I&C
- Electric power systems
- Control room
- Human factors
- Physical security and safeguards

Core Heat Removal

- Reactor design
  - Flow induced vibration
  - Coolant and cover gas purity

Reactivity Control

- Inherent protection
- Suppression of power oscillations
- Protection system functions/failure modes/reliability and testing
- System independence/separation of control and protection system
- Control system malfunctions/redundancy/capability
- Reactivity limits
- Protection against AOOs

Maintain Coolant Inventory

- Adequate coolant inventory
- Coolant boundary leak before break
- Inspection and surveillance
- Guard vessels
- Sodium leak detection

Reactor Residual Heat Removal

- RHR design
- Inspection, surveillance, and testing

Contain Radioactive Material

- Containment design and heat removal
- Fracture prevention
- Leak rate testing
- Penetrations
- Isolation
- Atmospheric control
- Inspection and testing
- Control and monitoring of radioactive releases
- Storage of waste

Prevent/Detect/Mitigate Energetic Reactions

- Sodium/concrete reaction prevention
- Sodium/air reaction prevention
- Sodium/water reaction prevention
- Fuel failure detection
  - Cover gas activity
  - Delayed neutron monitoring
- Recriticality prevention/mitigation

New Version of 54.1 Will Rely A Great Deal on the Original Version Which Was Deterministic with the Exception of:

- Risk informed in the area of accident selection
  - Frequency based
  - Consequence limited
- SSC safety class selection directly related to the PRA accident sequences (risk informed)
- PRA quality discussed
- QA graded using risk significance
- Use of single failure
- Addition of generic issues
  - Aging
  - Human performance
  - Security and safeguards (airplane crash)