An Overview of U.S. SFR General Design Criteria

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Safety Philosophy

- Safety philosophy guiding the design, construction, and operation of nuclear facilities in the U.S. is based on the principle of defense-in-depth (DiD).
  - Main DiD objective is to protect the health and safety of the public and plant operating personnel.
  - Fundamentally implemented by multiple, successive barriers to guard against the escape of radioactivity from nuclear facilities.
  - Extended and applied to all aspects of design, construction, and operation, so that all safety critical functions are achieved by multiple systems/procedures/processes that are diverse and independent.
- In design process, DiD principle has fostered the development of guidelines for identifying the system configurations and functional requirements that are important for safety.

SFR Safety Approach

- Like LWRs, SFR safety is first based on utilization of multiple redundant engineered protection systems to lower the probability of accident occurrence and to limit its consequences:
  - independent scram systems,
  - multiple coolant pumps and heat transport loops,
  - auxiliary decay heat removal systems, and
  - multiple barriers to release of radioactive materials.
- The safety design features that enhance inherent negative reactivity feedback and passive decay heat removal capabilities provide additional measures to protect the reactor even during very low probability accidents.

SFR Safety Approach (cont.)

- SFR safety analyses traditionally focus on double-fault events during which the reactor scram system is assumed to fail.
  - First fault can be any event that introduces significant unbalance between the heat production and removal.
  - Even though probability of double-fault events is very low, reactor must be designed to avoid core damage.
- This approach differs significantly from LWR safety analyses where the emphasis is usually on single-fault events.
  - Difference is due to the fact that SFR core is not in its most reactive configuration (core damage could lead to recriticality).
  - However, inherent safety characteristics of SFRs can provide large safety margins even for double-fault events.

SFR Safety Approach (cont.)

- Hypothetical Core Disruption Accidents (HCDAs) receive greater attention after Fukushima.
- Best approach to address HCDAs is to drive their probability below acceptable limits with enough certainty.
  - Inherent and passive safety measures can be used to reduce their likelihood to a level that they belong in residual risk category.
  - They can be handled with defense-in-depth considerations with adequate emergency planning.
  - Design features can be provided to reduce the impact of initiators with high uncertainty (i.e., seismic isolation against large earthquakes).

U.S. SFR Licensing Experience

- SFRs have long been both studied and operated by the DOE and its predecessor, AEC.
  - In addition to EBR-I, EBR-II, Fermi and FFTF, DOE-complex designed, built and operated a wide range of fast reactor related experimental facilities.
  - Past and present SFR R&D programs have focused on development and demonstration by testing of the concepts with passive safety features that lead to no serious consequence.
- The current U.S. SFR licensing experience comes from the Clinch River Breeder Reactor (CRBR) and the Advanced Liquid Metal Reactor (ALMR) program interactions with the U.S. Nuclear Regulatory Commission (NRC) for review of PRISM (GE) and SAFR (Rockwell/Westinghouse) concepts.

U.S. Safety Design Criteria

- System configurations and functional requirements important for safety are documented in a set of safety design criteria.
  - Commercial NPPs licensed by USNRC must comply with general design criteria documented in Code of Federal Regulations
    - 1OCFR5O, App. A, generally applicable to LWRs
  - Modifications of these criteria for application to LMR designs were proposed by the nuclear power industry
    - ANSI/ANS-54.1, General Safety Design Criteria for a Liquid Metal Reactor Nuclear Power Plant (currently undergoing a review and update)
  - Finally, the nuclear research reactors built by the U.S. Department of Energy (USDOE) (not licensed or regulated by USNRC) must comply with the criteria documented in a DOE Order.
    - U.S. Department of Energy, Nuclear Reactor Safety Design Criteria, Order DOE 5480.30

U.S. Safety Design Criteria (cont.)

- Recently, a comparison of SDC under 10CFR50 Appendix A, ANSI/ANS 54.1, and DOE Order 5480.30 was performed under the U.S.DOE's Advanced Reactor Concepts (ARC) Program:
  - Cross comparison of criteria defined by the USNRC, ANSI/ANS, and USDOE are generally convergent in regard to scope and content.
  - Most of the 10CFR50 criteria are directly applicable to SFRs without wording changes or modifications.
  - About twenty 10CFR50 criteria worded with reference to specific LWR design features require modification to preserve the original intent for liquid sodium coolant.
  - About ten additional criteria relevant to liquid metal (sodium) cooled nuclear plant designs that are not explicitly stated in 10CFR50 are identified.

ANS 54.1 Review and Update

- U.S.NRC uses the GDC as acceptance criteria during the review of the applicant's safety analysis report
- During the CRBR licensing, a revised set of GDC was developed and later used to review the preliminary design information documentation for the PRISM and SAFR concepts
- Later incorporated into a standard by the ANSI/ANS
  - Defines safety objectives, general design criteria, selection of LBE's, and classification of SSC's
  - Intended to provide assurance that an SFR can be operated with acceptable risk to public health and safety of the environment
  - Focus on the design--criteria for adequately executing construction and safely operating the plant are outside the scope
- Standard was withdrawn in 1989 because of decline of the US sodium reactor program

ANS 54.1 Review and Update (cont.)

- ANS 54.1 update is in the final stages of review within the working group. In overall approach, consideration is given to:
  - Regulatory Interface
  - Defense in Depth
  - Probabilistic and Deterministic Design Criteria (risk-informed and performance-based)
  - High Level Safety Objectives
  - Plant/Design Maturity Level
- Additional design requirements (not specific to SFRs)
  - Aging Management
  - Human Factors
  - Physical Security /Safeguards
  - Emergency Access
  - Fuel Failure Detection

ANS 54.1 Review and Update (cont.)

- Process for creating SFR GDC is based on the General Design Criteria from 10CFR50 App. A
  - Keep existing DGC where applicable (including the numbering)
  - Minor modifications to reflect SFR vs LWR terminology
  - Major changes based on unique SFR characteristics
  - New GDC to reflect unique SFR characteristics (10)
  - Addition of GDC (not SFR-specific) needed -post Fukushima (9)
- Addresses Beyond Design Basis Accidents
  - Station Blackout
  - ATWS
  - Aircraft Impact
  - Severe Accident (prevention and mitigation)
- Did not address new IAEA DEC condition
  - Not part of the US licensing process