DEVELOPMENT AND MODERNIZATION OF THE ANSI/ANS-54.8 LIQUID METAL FIRE PROTECTION STANDARD

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BACKGROUND & OBJECTIVES

- Objective: Reissue and revise the ANS-54.8-1988 standard (withdrawn in 2000).
- Listed on the NEI and ARCSC list of standard needs for advanced reactors.

Drivers & Motivators

1. Recognized limitations in existing sodium fire modeling capabilities.
2. Need to support robust, defensible safety evaluations for contemporary licensing decisions.
3. Challenges with strictly deterministic, prescriptive guidance, which can lead to excessive conservatism and costly designs.

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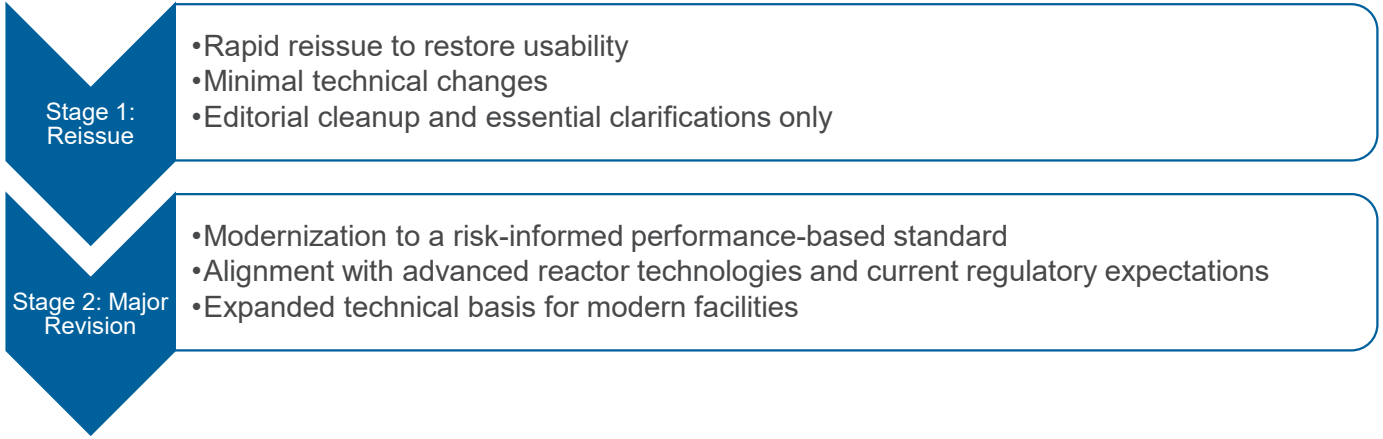
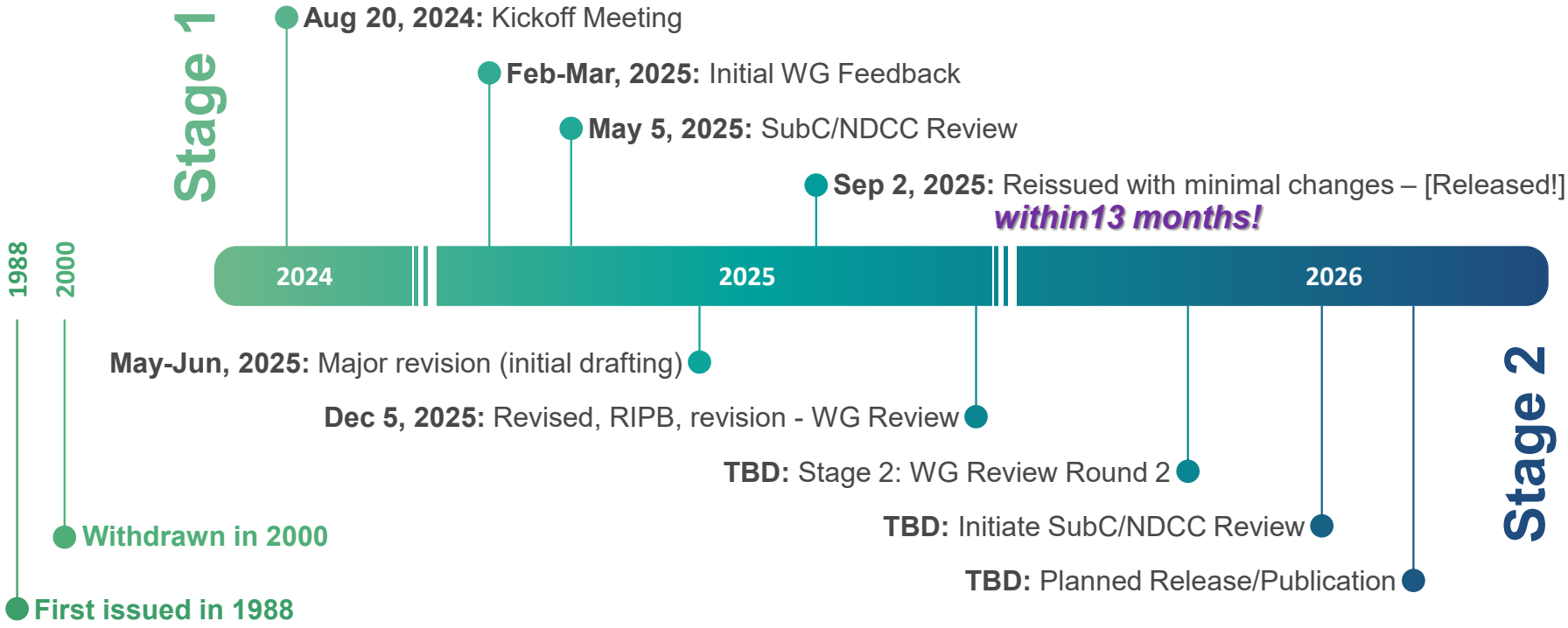
MODERNIZATION STRATEGY

- It is within the ANSI/ANS consensus standards process.
- A staged approach (reissue followed by modernization):



- Maintaining continuous regulatory engagement.

TIMELINE & PROGRESS



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STAGE 1: REISSUING WITH MINOR EDITS

[Completed]

- **Targeted language clarifications:** Minimal editorial changes and modifications that are critical to provide more clarity to the language.
  - For example: Changing the title and scope to only focus on Sodium/NaK fires (since there are no other relevant liquid metals.

- **Bridging the Transition for Reference Updates**
  - Updated statement: “Only the standards explicitly referred to in this document qualify as references. Subsequent revisions of these standards shall not be substituted.”

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STAGE 2: REVISION SCOPE AND APPROACH

[Ongoing]

Content Updates

- **Revise the structure** and reorganize the standard to improve usability and alignment across sections.
- **Enhance the technical basis and scope** (e.g., consideration of different types of facilities, outdated references, technical terms, etc.)
- **Update the fire protection features** and capabilities.

Methodological Updates

- Modernize the standard with a **risk-informed, performance-based** framework aligned.
- Introduce an **iterative graded and streamlined implementation approach** to ensure flexible, proportional application across a wide range of facilities.
- **Explicitly introduce financial aspects** and asset risk management as optional considerations in the process.

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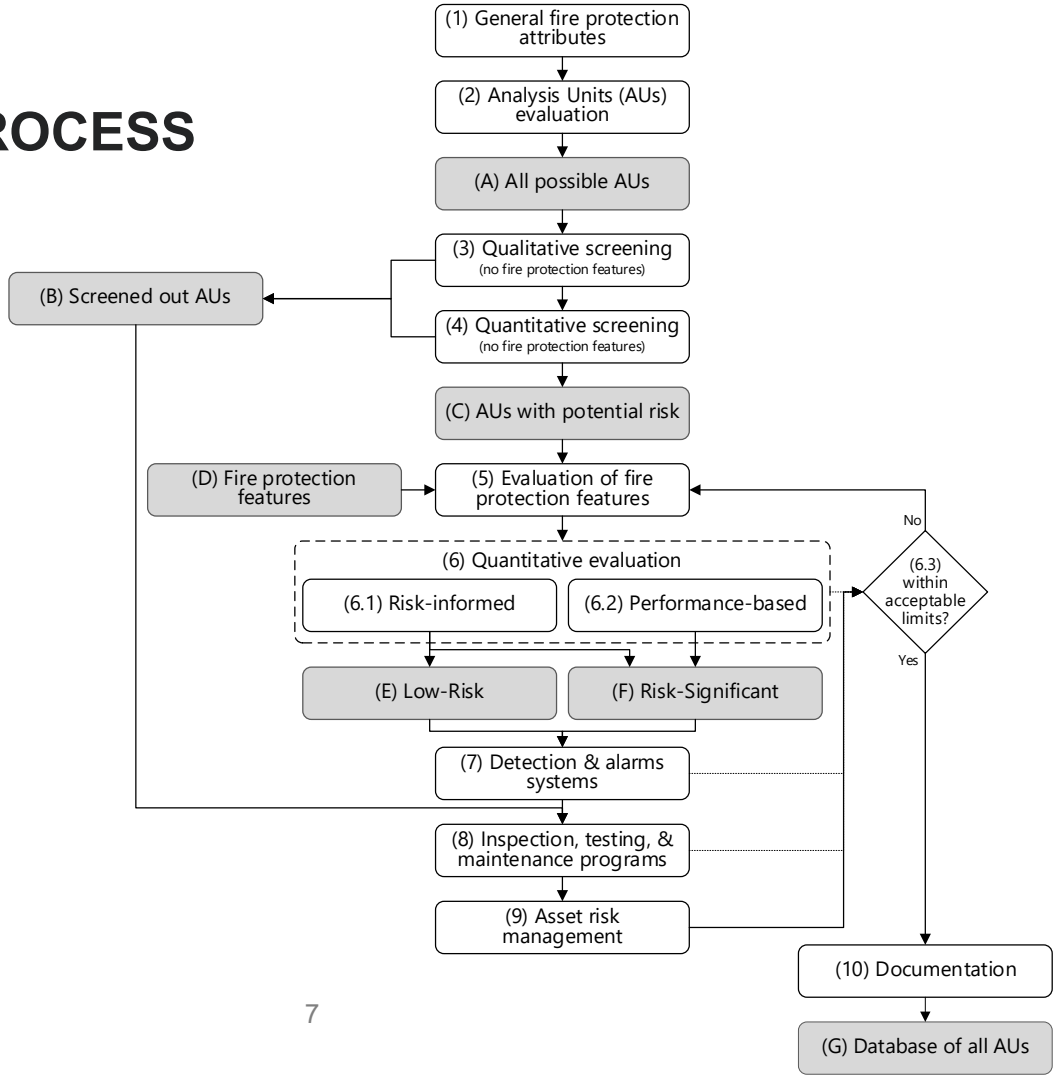
STAGE 2: IMPLEMENTATION PROCESS



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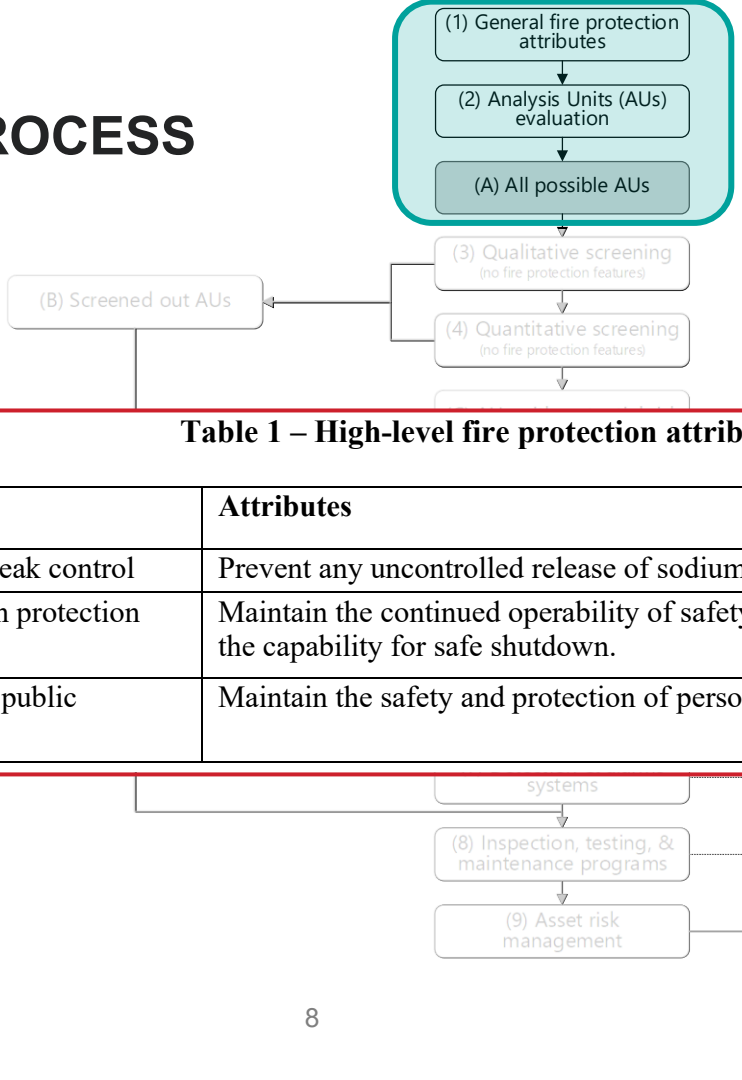
STAGE 2: IMPLEMENTATION PROCESS



- Establish the general fire protection attributes.
- Identify analysis units (AUs) or hazard progression scenarios.

Table 1 – High-level fire protection attributes

Category	Attributes
Sodium/NaK leak control	Prevent any uncontrolled release of sodium/NaK inventories.
Safety function protection	Maintain the continued operability of safety-significant functions, including the capability for safe shutdown.
Personnel and public protection	Maintain the safety and protection of personnel and the public at all times.

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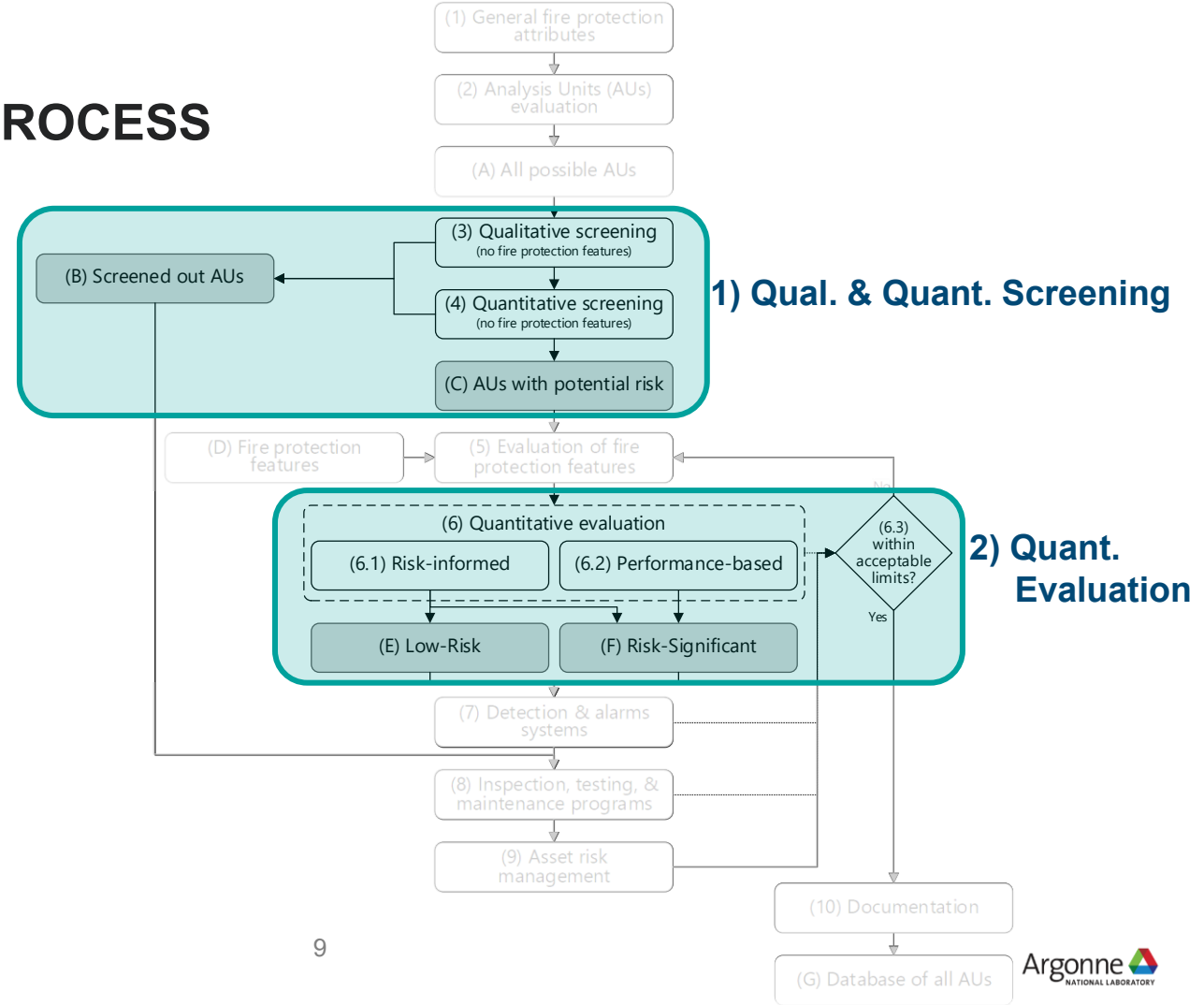
STAGE 2: IMPLEMENTATION PROCESS

RIPB Steps:



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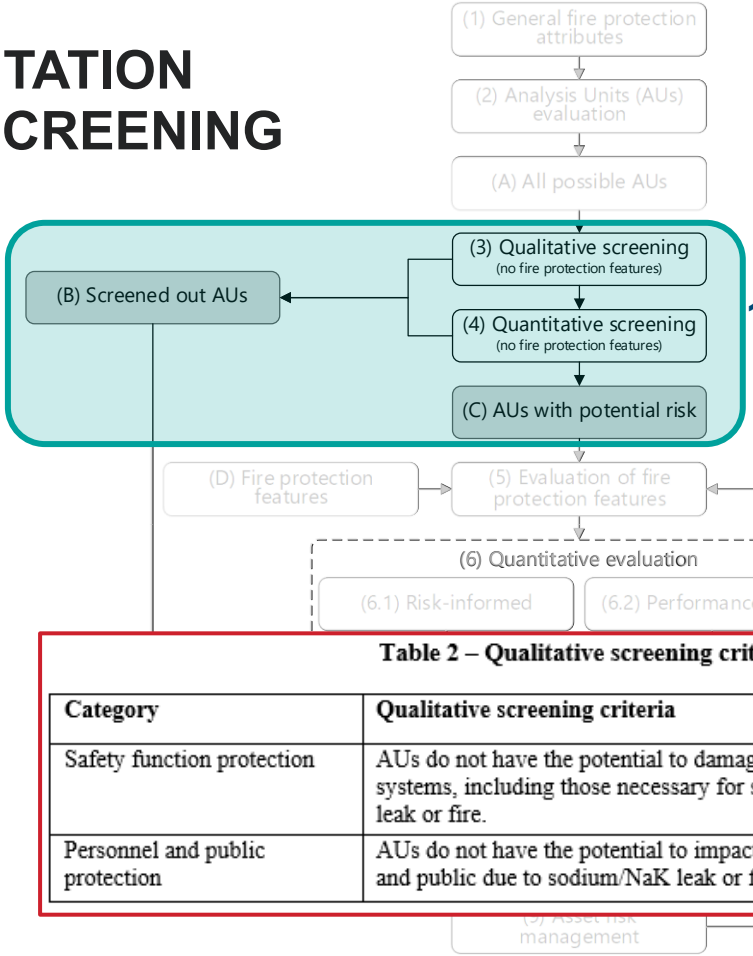
STAGE 2: IMPLEMENTATION PROCESS – QUAL. SCREENING

- ***Without*** *consideration of any fire protection features, and while still crediting the general fire protection attribute…*
- In Step 3, a **qualitative screening** analysis is conducted to determine which AUs will require further evaluation.



1) Qual. & Quant. Screening

Table 2 – Qualitative screening criteria

Category	Qualitative screening criteria
Safety function protection	AUs do not have the potential to damage any safety-related equipment or systems, including those necessary for safe shutdown, due to sodium/NaK leak or fire.
Personnel and public protection	AUs do not have the potential to impact the health and safety of personnel and public due to sodium/NaK leak or fire, including combustion products.

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STAGE 2: IMPLEMENTATION PROCESS – QUANT. SCREENING

- ***Without*** *consideration of any fire protection features, and while still crediting the general fire protection attribute…*
- For the AUs which are retained after the qualitative screening, a preliminary **quantitative screening** is conducted in Step 4.

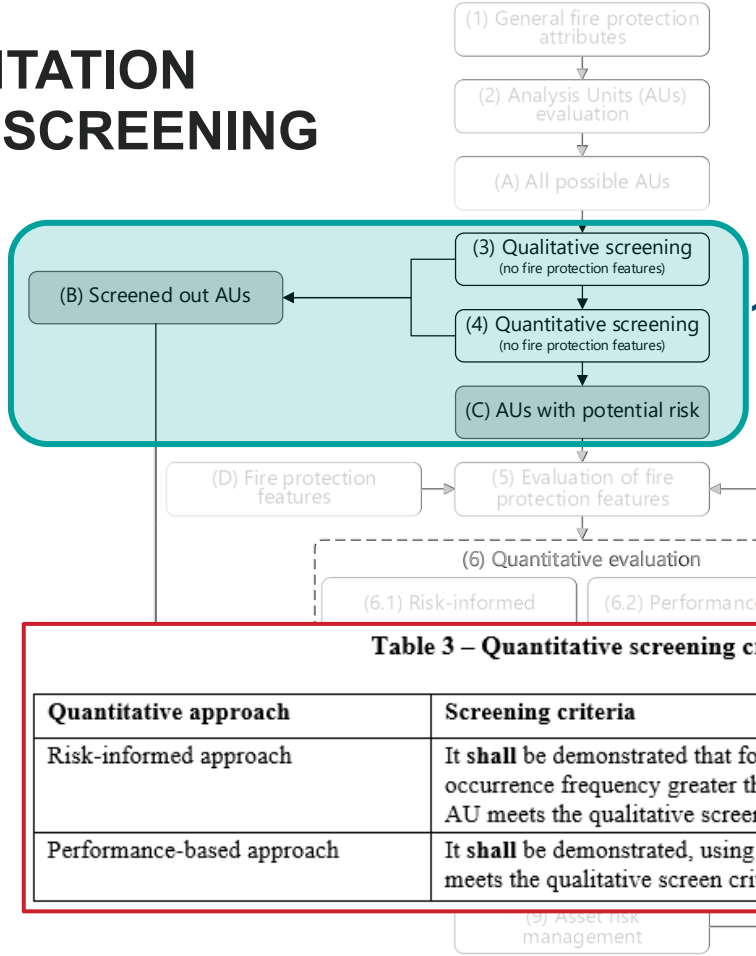

Table 3 – Quantitative screening criteria

Quantitative approach	Screening criteria
Risk-informed approach	It **shall** be demonstrated that for an event or scenario[8] with a mean occurrence frequency greater than $1x10^{-7}$ per effective-year[9] that the AU meets the qualitative screen criteria stated in Table 2.
Performance-based approach	It **shall** be demonstrated, using conservative assessments, that the AU meets the qualitative screen criteria stated in Table 2.

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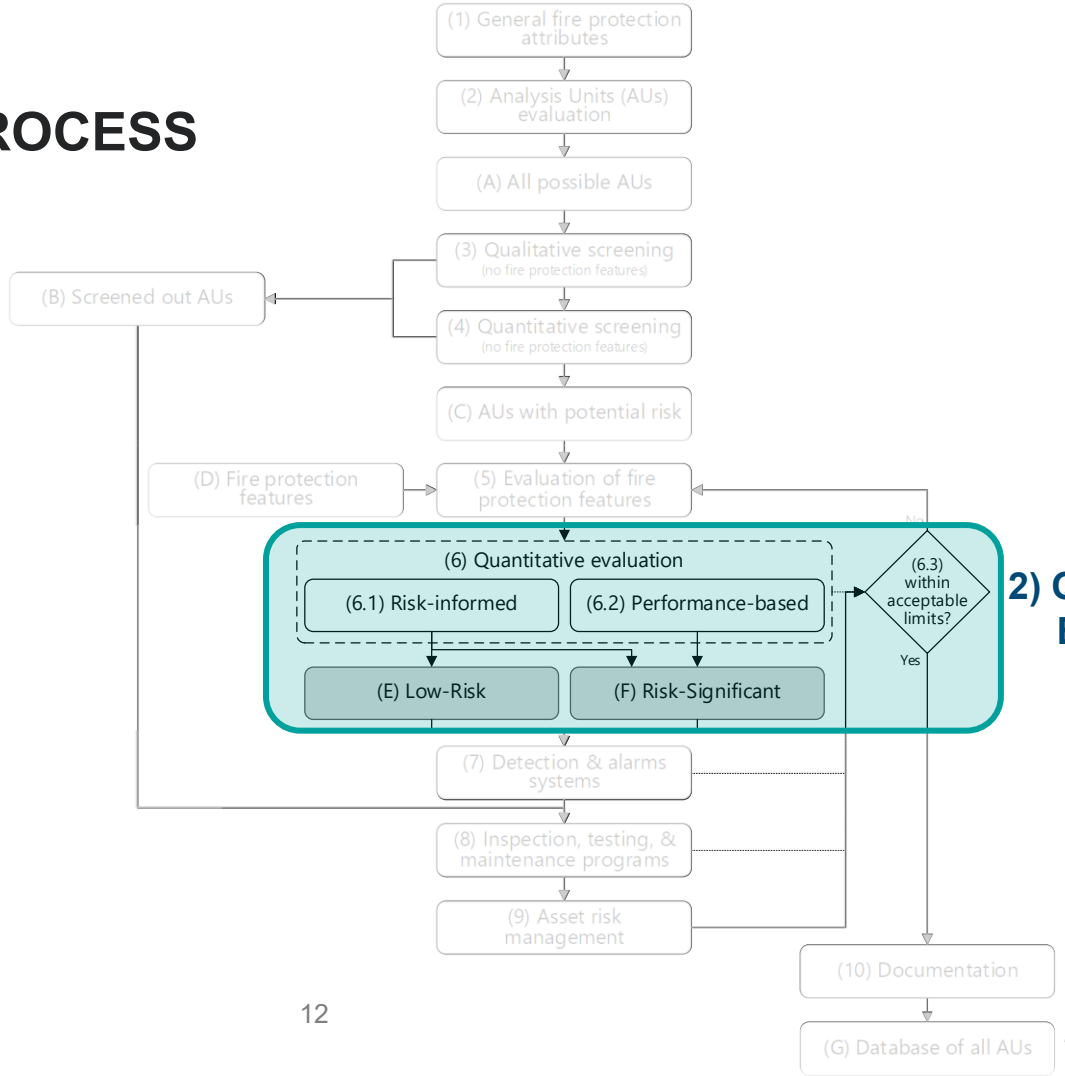
STAGE 2: IMPLEMENTATION PROCESS

- *With consideration of the fire protection features, the AUs are evaluated quantitatively in Step 6.*
- The quantitative evaluation can be conducted through:
  - A risk-informed approach (Step 6.1), or
  - A performance-based approach (Step 6.2).
- The evaluated metrics are compared, in Step 6.3, against established performance metrics and quantitative screening criteria.



2) Quant. Evaluation

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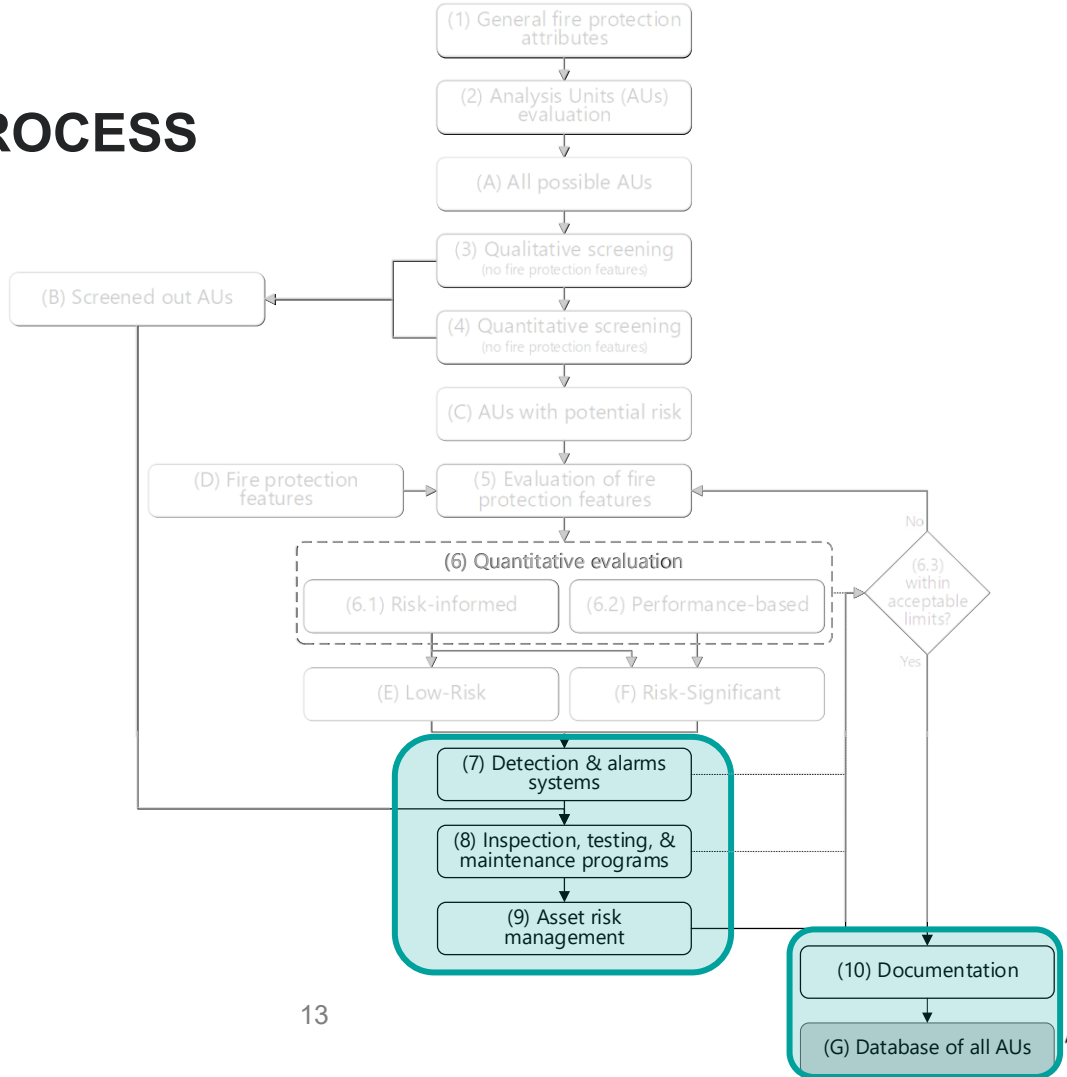
STAGE 2: IMPLEMENTATION PROCESS

- For all retained AUs:
  - The detection and alarms systems (Step 7), and
  - The programs for testing, inspection, maintenance, and quality assurance (Step 8),

  are evaluated.
- Financial consequences are evaluated in Step 9 (not a requirement).
- Everything is to be documented with the appropriate level of technical details in Step 10.



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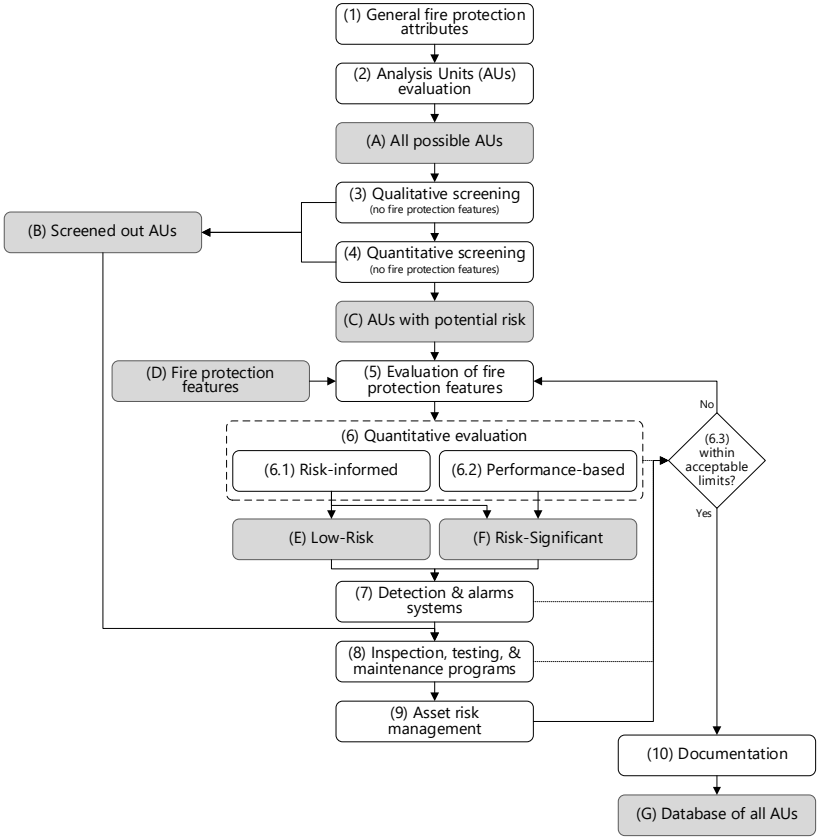
STAGE 2 UPDATES

Implementation Process

Table B-1: Mapping of Implementation Process Steps to Standard Sections

Steps (Fig. 1)	Related Sections	Description
Step 1	Sec. 4	Establish general fire protection attributes
Step 2 / Item A	Sec. 5.1	Identify Analysis Units (AUs) and scenarios
Step 3 / Items B & C	Sec. 5.2	Qualitative screening of AUs; qualitatively identify AUs with potential risk (C) and screened-out AUs (B)
Step 4 / Items B & C	Sec. 5.3	Quantitative screening of AUs; quantitatively identify AUs with potential risk (C) and screened-out AUs (B)
Step 5 / Item D	Sec. 6	Preliminary identification of fire protection features
Steps 6.1 & 6.2 / Items E & F	Sec. 5.5	Detailed quantitative evaluation: risk-informed or performance-based categorization of AUs
Step 6.3	Sec. 5.4	Comparison against performance metrics and acceptability criteria, including treatment of uncertainty
Step 7	Sec. 7	Evaluation of detection and alarm systems
Step 8	Sec. 8	Evaluation of testing, inspection, and maintenance programs
Step 9	Sec. 9	Evaluation of financial consequences (including screened-out AUs)
Step 10 / Item G	Sec. 10	Adequate documentation



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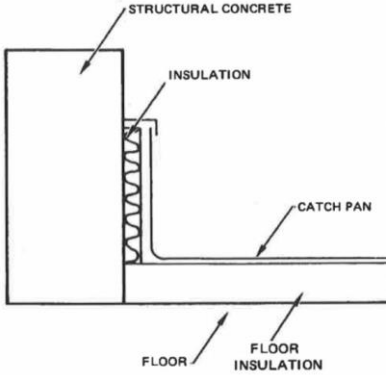
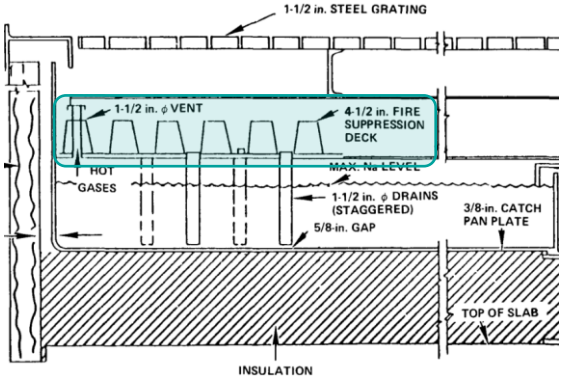
STAGE 2 UPDATES

Fire Protection Features

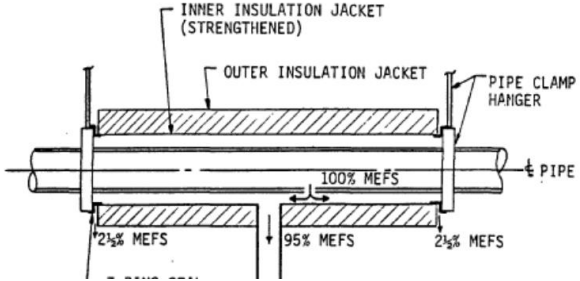
- Inert atmospheres
- Sodium fire suppression systems
  - Inert gas flooding systems
  - Dry-powder suppression systems
- Protection of concrete and steel structures
  - Concrete structures
  - Steel liners
  - Catch pans
  - Sodium dumping
  - Materials for protective barriers
- Guard pipe or double-walled piping
- Smoke control
- Fire suppression deck
- Insulation and leak jackets
- Collection tanks and vaults
- Water and other reactants
- Portable extinguishers and personnel safety



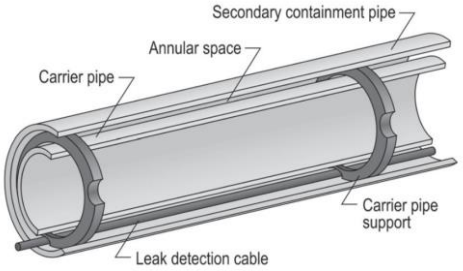
Example Catch Pan Design [1]



Example Suppression Deck System Design [2]



Example of Pipe Insulation Jacket and Drain Pipe Configuration [3]



Example of Double-walled Piping Layout [4]

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STAGE 2 UPDATES

Other Updates

- Updated references:

[1] NUREG-6850 (EPRI 1011989), *Fire PRA Methodology for Nuclear Power Facilities*, U.S. Nuclear Regulatory Commission, Washington, DC (2005).

[2] *Code of Federal Regulations*, Title 10, "Energy," Part 100, "Reactor Site Criteria," U.S. Nuclear Regulatory Commission (2017).

[3] ACI 349-23, *Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary*, American Concrete Institute, Farmington Hills, MI (2023).

[4] *Code of Federal Regulations*, Title 10, "Energy," Part 20, "Standards for Protection Against Radiation," U.S. Nuclear Regulatory Commission (2021).

[5] *Code of Federal Regulations*, Title 10, "Energy," Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission (2025).

[6] NFPA 10-2026, *Standard for Portable Fire Extinguishers*, National Fire Protection Association, Quincy, MA (2026).

[7] *Code of Federal Regulations*, Title 10, "Energy," Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix R, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," U.S. Nuclear Regulatory Commission (2021).

[8] NFPA 72-2025, *National Fire Alarm and Signaling Code*, National Fire Protection Association, Quincy, MA (2022).

[9] NFPA 70-2026, *National Electrical Code*, National Fire Protection Association, Quincy, MA (2026).

- Editorial cleanup and formatting improvements
- Updated definitions and acronyms
- Introduced Appendix B explanatory material

ANS-54.8 AND OTHER C&Ss

Other fire protection codes and standards

- Sec. 1.4 Limit of Applications: “The intent of this standard is to provide requirements and guidance on those aspects of fire prevention and protection that are not covered in other codes and standards.”
- Sodium leaks and fires are typically treated in separate chapters and require more detailed analysis process.

Other RIPB codes and standards

- Inspired by codes like NFPA 805, but without requiring a full fire PRA.
- Following ANS guidance: “Incorporating Risk-Informed and Performance-Based Approaches/Attributes in ANS Standards.”

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TAKEAWAYS

- ANS-54.8 has been successfully reissued with minor, targeted edits to restore near-term usability. *13 months from kickoff meeting to reissue.*
- Stage 2 is actively modernizing the standard to support sodium/NaK fire protection for various types of facilities.
- A risk-informed, performance-based graded framework is being introduced to enable flexible, proportional application.
- Demonstrate the benefit of continuous NRC engagement throughout the C&S development process.

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REFERENCES

1. M. Bucknor, "The Versatile Test Reactor (VTR) Approach to Sodium Fire Hazard Analysis and Protection System Methodology," Proceedings of the 2022 International Conference on Fast Reactors and Related Fuel Cycles (FR22), 202
2. K. Buttrey, "CRBRP Sodium Fire Protection System Design," ESG-DOE-13428, 1984.
3. I. Burns and Roe, "Sodium Fire Testing: Structural Evaluation of Sodium Fire Suppression System," DOE/CL/98004-03, 1984.
4. L. Cadwallader and T. Pinna, "Reliability Estimation for Double Containment Piping," Proceedings of the 20th ANS Topical Meeting on the Technology of Fusion Energy, 2012.

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