NBSR Safety Classification of Structures, Systems, and Components

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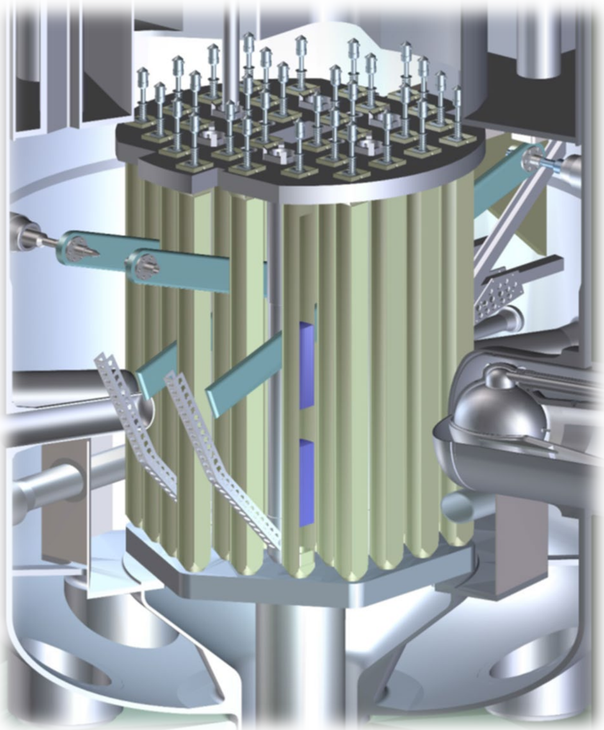
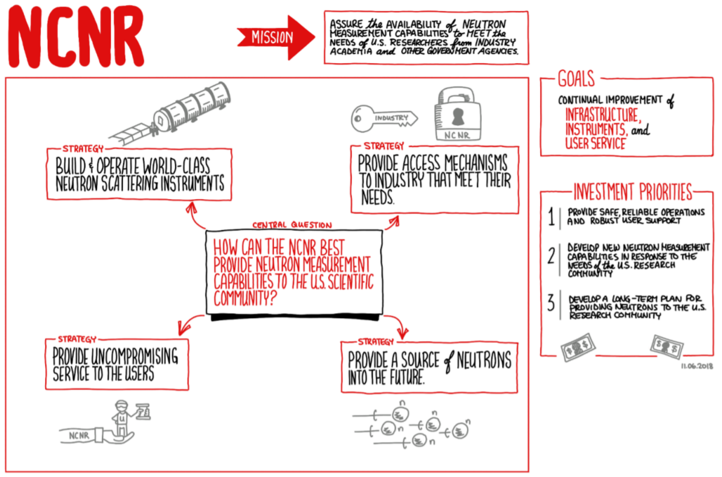
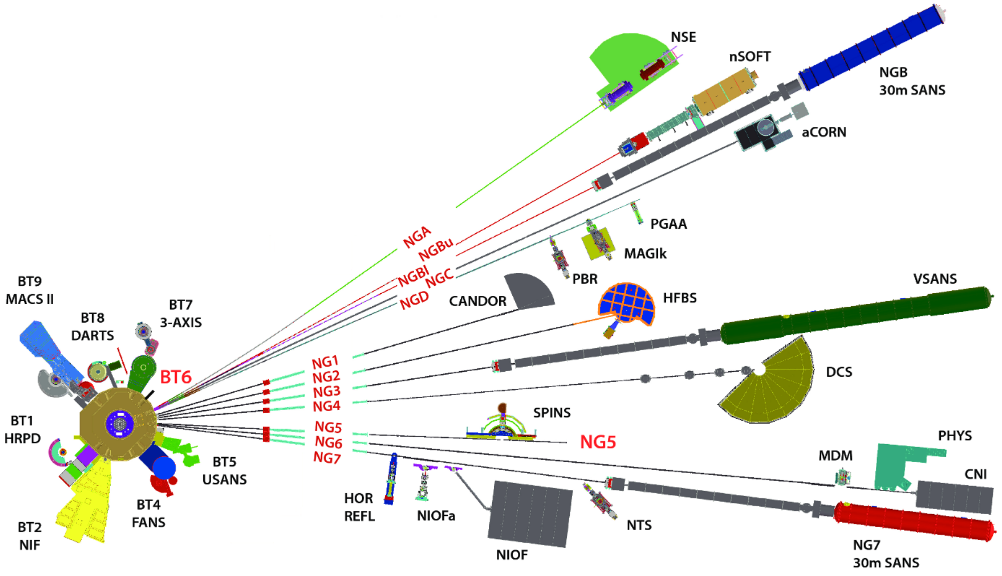
The NIST Center for Neutron Research - NCNR

National Bureau of Standards Reactor (NBSR)

- **Location**: Situated at the NIST Center for Neutron Research (NCNR) in Gaithersburg, MD.
- **Power**: Operates at 20 MW thermal power.
- **Fuel**: Uses 93% enriched UO_2 plate-type fuel.
- **Coolant and Moderator**: Heavy water (D_2O) is used as the coolant, moderator, and reflector.
- **Applications**: Primarily used for neutron science applications, supporting a variety of research activities.
- **History**: Operational since 1967, it's one of the five high-performance research reactors in the U.S.







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Introduction: Safety Classification of SSC

- **What are SSCs?**
  - Structures, Systems, and Components critical to the operation and safety of facilities.
- **Why Safety Classification?**
  - To identify and prioritize SSCs based on their impact on safety and operational reliability. Define QA, Maintenance, Monitoring levels.
- **Significance:**
  - Ensures robust safety management.
  - Helps in risk assessment and mitigation.
  - Essential for regulatory compliance and public trust.
- **Common Applications:**
  - Nuclear power plants
  - Chemical processing facilities
  - Industrial manufacturing units

Key Objectives:

Safety Classification of Structures, Systems, and Components (SSCs)

- **Definition:**
  - Categorizing SSCs based on their importance to safety.
- **Purpose:**
  - Ensure appropriate design, quality, and operational standards.
  - Prioritize safety measures and resource allocation.

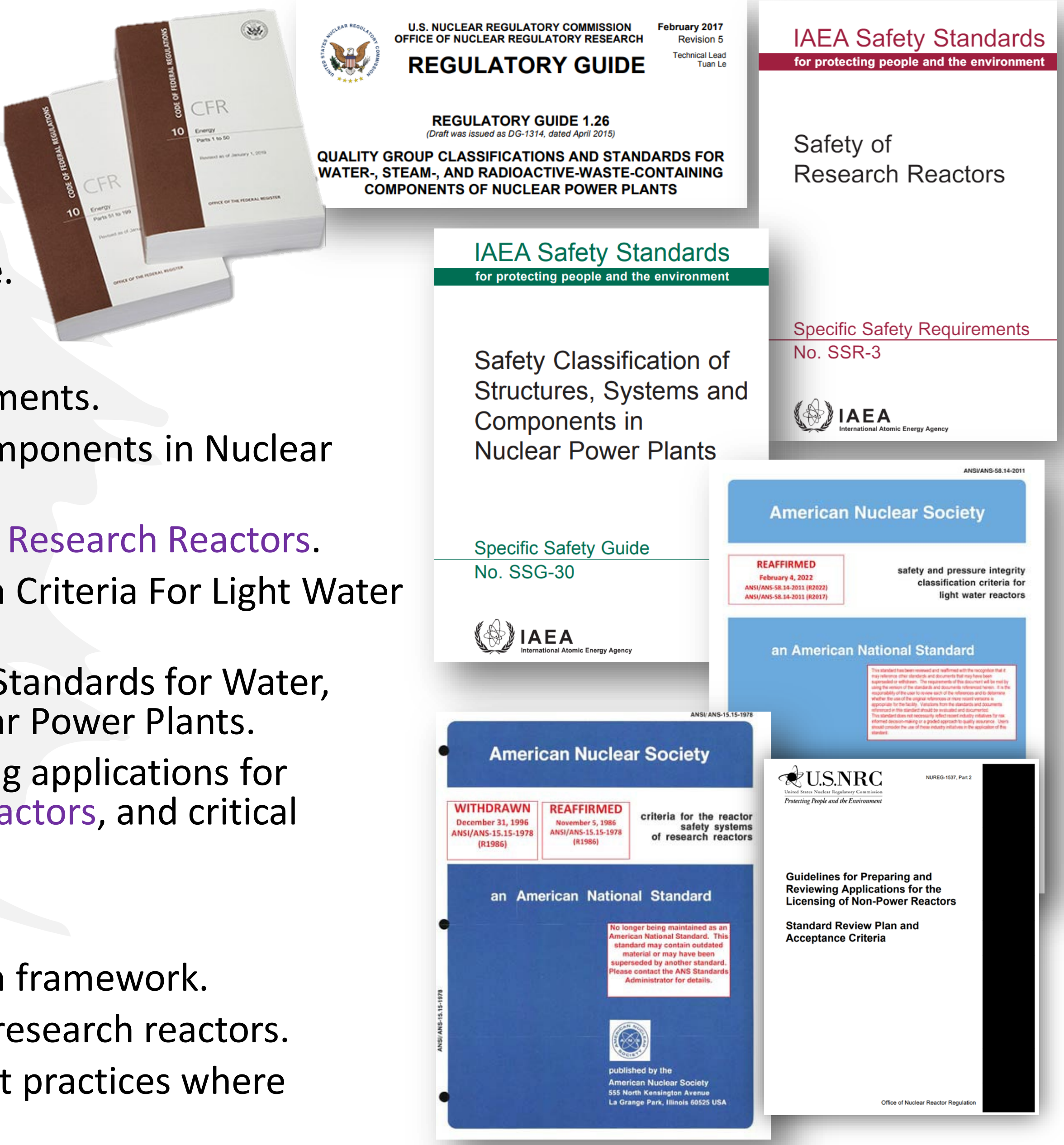
Key Objectives:

- **Address safety classification and quality requirements for key SSCs within the NBSR.**
- **Focus on SSCs essential for operational functionality and protection from radiological releases.**
  - Develop a systematic approach to safety considerations.
  - Implement a methodical classification of SSCs for design and analysis purposes.
- **Approach applicable to other critical systems as determined by facility management.**
  - Protect public health and safety.
  - Minimize environmental impact.
  - Maintain reliability and integrity of SSCs.
- **Regulatory Framework:**
  - Integrate guidance from international and national standards (e.g., IAEA, NRC etc.).

Methodology:

- **Absence of Solid Standards for Research Reactors:**
  - Research reactors lack universally accepted, solid standards.
  - Existing "standards" provide guidance but are not comprehensive.
- **Key Standards Referenced:**
  - IAEA SSR-3: Safety of Research Reactors - Specific Safety Requirements.
  - IAEA SSG-30: Safety Classification of Structures, Systems, and Components in Nuclear Power Plants.
  - ANSI/ANS-15.15-1978: Criteria for The Reactor Safety Systems Of Research Reactors.
  - ANSI/ANS-58.14-2011: Safety and Pressure Integrity Classification Criteria For Light Water Reactors.
  - USNRC Regulatory Guide 1.26: Quality Group Classifications and Standards for Water, Steam, and Radioactive-Waste-Containing Components of Nuclear Power Plants.
  - NUREG-1537: USNRC set of guidelines for preparing and reviewing applications for licensing non-power reactors, including research reactors, test reactors, and critical assemblies.

- **Comprehensive Assessments Conducted:**
  - Leveraged existing standards to form a robust safety classification framework.
  - Evaluated the applicability of standards to the unique context of research reactors.
  - Ensured alignment with regulatory expectations and industry best practices where possible.



Methodology: SSC classification

Functions credited in the safety assessment	Severity of the consequences if the function is not performed		
	High	Medium	Low
Reach a controlled state after AOO	SC-1	CS-2	CS-3
Reach a controlled state after DBA	SC-1 or SC-2	SC-2 or CS-3	Non-Nuclear
Reach a controlled state after DEC	SC-2 or CS-3	Non-Nuclear	Non-Nuclear

Severity	Criteria (Based on US NRC sections 10CFR20, 10CFR50.67, and 10CFR100.11)
Low	Personnel in facility or at exclusion area boundary: TEDE ≤ 5 rem. Public outside restricted area: TEDE ≤ 0.1 rem (excluding background radiation).
Medium	Personnel in facility or at exclusion area boundary for 2 hours post-release: Whole body dose ≤ 25 rem, thyroid dose (CDE) ≤ 300 rem. Public beyond exclusion area boundary TEDE > 5 rem.
High	Public beyond exclusion area boundary: TEDE > 25 rem, thyroid dose (CDE) > 300 rem. Personnel at exclusion area boundary for 2 hours post-release: TEDE ≤ 25 rem, thyroid dose (CDE) ≤ 300 rem.

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SSC Classification Based on FSAR Analysis

Functions credited in the safety assessment	Severity of the consequences if the function is not performed		
	High	Medium	Low
Reach a controlled state after AOO	SC-1	CS-2	CS-3
Reach a controlled state after DBA	SC-1 or SC-2	SC-2 or CS-3	Non-Nuclear
Reach a controlled state after DEC	SC-2 or CS-3	Non-Nuclear	Non-Nuclear

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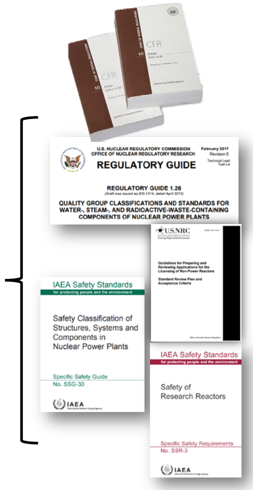


1. **Examination of FSAR (Final Safety Analysis Report):**
   Focus on Chapter 13 which describes accidents (DBA, DEC, and MHA) and their radiological consequences.
2. **Analysis of Radiological Consequences:**
   Assess Total Effective Dose Equivalent (TEDE) for each scenario.
3. **Identification of SSCs:**
   Identify Structures, Systems, and Components (SSCs) involved in mitigating or dealing with the accidents.
4. **Safety Classification:**
   Label each SSC with the appropriate Safety Class (SC) based on their role and the severity of consequences.

This approach ensures a structured and thorough analysis of SSCs based on their importance in mitigating radiological consequences, aligning with regulatory requirements and safety standards.

Examination of NBSR FSAR

- Accident Scenarios:
  - Excess Reactivity (RIA)
  - Loss of Primary Coolant (LOCA)
  - Loss of Primary Coolant Flow (LOFA and SBO)
  - Misloading of Fuel
  - Maximal Hypothetical Accident (MHA)
    - Fuel Channel Blockage and Fuel Plate Melting
- Key Findings:
  - Maximal Hypothetical Accident (MHA): Poses the highest radiation hazard to personnel and the public.
  - Other scenarios do not present a significant risk of fuel cladding failure or release of fission as well as radioactive products.

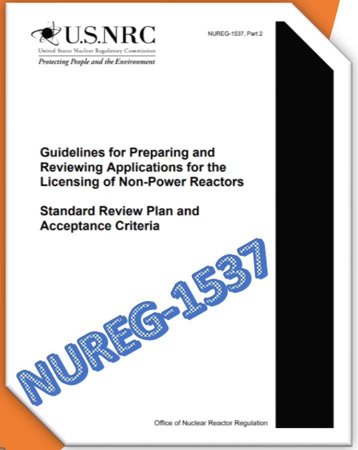
Conclusion: Based on NRC's Safety Evaluation Report (SER) for NBSR (ML090990135), radiation doses in the MHA scenario are within acceptable limits, allowing SSCs to be classified as Non-Nuclear.

Radiation Consequence Conflict in DBAs Amid SSC Mitigation Failures

Functions credited in the safety assessment	Severity of the consequences if the function is not performed		
	High	Medium	Low
Reach a controlled state after AOO	SC-1	CS-2	CS-3
Reach a controlled state after DBA	SC-1 or SC-2	SC-2 or CS-3 ? ⇐	**Non-Nuclear**
Reach a controlled state after DEC	SC-2 or CS-3	Non-Nuclear	Non-Nuclear

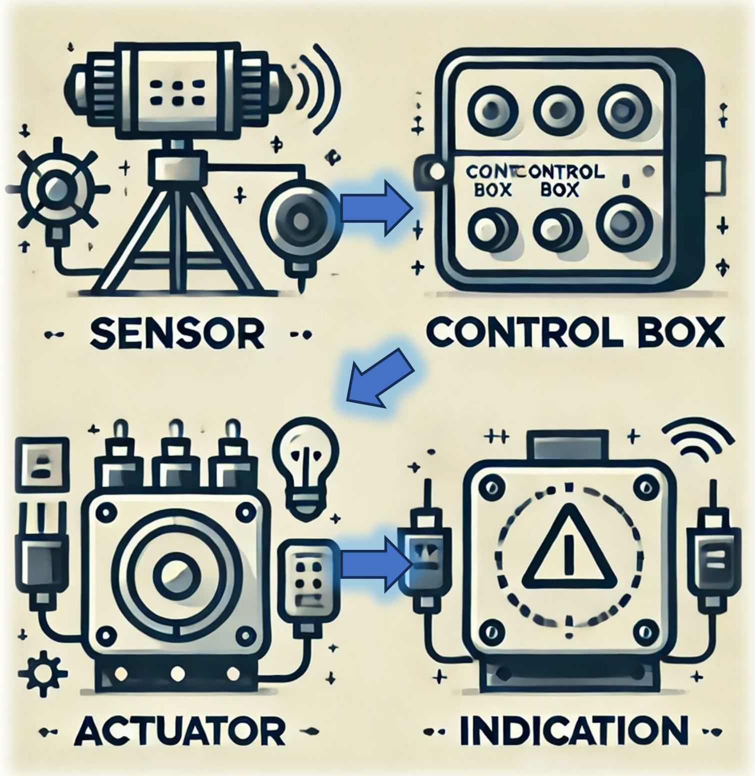
Structures Systems and Components (SSCs) used as Engineering Safety Systems or Engineered Safety Features (ESF)

- In NUREG-1537, a dual failure scenario, where a Design Basis Accident (DBA) occurs concurrently with the failure of supporting Structures, Systems, and Components (SSCs) that mitigate or eliminate accident progression (ESF), would typically be considered a Beyond Design Basis Accident (BDBA) or a Design Extension Condition (DEC).
- SSCs that mitigate or eliminate accident progression (ESF) can be classified as non-nuclear; however, they require a comprehensive maintenance and examination program to ensure sufficient availability and a low probability of failure, thereby maintaining their readiness and effectiveness.



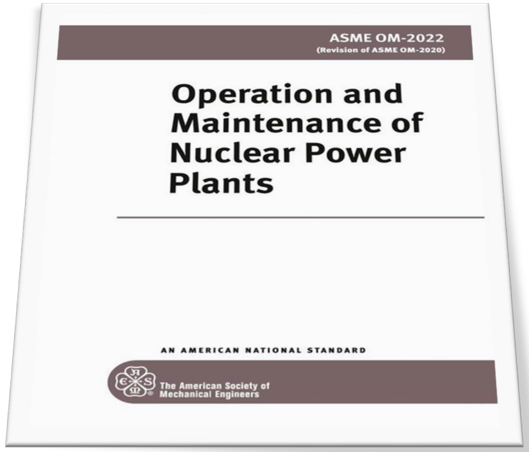
Screening of SSCs Used as Engineering Safety Systems (ESS) or Engineered Safety Features (ESF)

- **Screening of SSCs**: Involves thorough evaluation for all Design Basis Accidents (DBAs) including Reactivity Insertion Accident (RIA), Loss of Coolant Accident (LOCA), Loss of Flow Accident (LOFA), and Station Blackout (SBO).
- **Engineering Safety Systems (ESS) and Engineered Safety Features (ESF)**: These systems are described in detail in the NBSR FSAR. We screen to identify components whose failure would result in accident consequences beyond those analyzed in NBSR FSAR.
- **Major Components**: The SSCs used as Engineering Safety Systems (ESS) or Engineered Safety Features (ESF) include four major components:
  - Sensor: Detects conditions that require a safety action.
  - Control Box: Processes signals from sensors and initiates the safety action.
  - Actuator: Carries out the physical action required to ensure safety.
  - Indication: Provides feedback and status to ensure that the safety action has occurred.
- **Safety Assurance**: These components collectively ensure that the safety actions are effectively implemented.



Inspection and Maintenance of Key SSCs

- Importance of Inspection and Maintenance:
  - Ensures the integrity and effectiveness of safety systems.
  - Critical for detecting deviations, anomalies, or potential failures.
  - Includes proactive measures for preserving, repairing, or replacing components.
- Identified Components:
  - **Reactor Safety System**: Ensures the reactor operates safely under all conditions.
  - **Pumps**: Circulate coolant and other fluids essential for reactor operation.
  - **Valves**: Control the flow of fluids within the reactor systems.
  - **Diesel Generator Units**: Provide backup power during electrical outages.
  - **UPS Systems**: Ensure continuous power supply to critical systems.
  - **Switches and Switchgears**: Manage electrical power distribution and control.
  - **Sensors and Position Switches**: Monitor system conditions and provide necessary feedback.



- Adopted Standards:
  - **ASME OM-2022**: Establishes requirements for preservice and in-service testing and examination of components to assess operational readiness in light-water reactor nuclear power plants.
  - **NFPA 70B**: Provides guidelines for developing and implementing an Electrical Maintenance Program (EMP) to safeguard against electrical system failures.

Inspection and Maintenance Intervals:

To ensure the safety and reliability of the reactor safety system, a rigorous schedule of inspection and maintenance is essential. Each component type has specific intervals for testing and maintenance activities to detect anomalies, ensure operational readiness, and prevent potential failures. The following outlines the detailed inspection and maintenance intervals for critical components.

- **Reactor Safety System (SCRAM logic):**
  - **Testing Frequency:** Approximately three times per year (before each core cycle).
  - **Maintenance:** Annual visual inspection and electrical resistance tests.

- **Sensors and Position Switches**
  - **Testing Frequency:** Conducted annually for SIL 3-rated components, unless specified otherwise by the vendor.
  - **Testing Methods:**
    - **Functional Tests:** Validate the functionality of sensors under controlled conditions.
    - **Calibration Checks:** Ensure the accuracy of sensors by comparing their readings against known standards and adjusting, as necessary.

Inspection and Maintenance Intervals:

- **Pumps**:

In-service test parameters for pumps

Quantity	Instrument Accuracy, %	Test frequency	
		Quarterly	Annually
Speed, N	±2	X	X
Differential pressure, ΔP	±2	X	X
Discharge pressure, P	±2		X
Flow rate, Q	±2	X	X
Vibration	±5 (4-1000 Hz) and ±15 (1-4 Hz)		X

Test acceptance criteria for pumps

Test Parameter	Acceptable Range	Alert Range	Required Action Range	
			Low	High
Differential pressure, ΔP	$0.93\Delta Pr$ to $1.06\Delta Pr$	$0.90\Delta Pr$ to $<0.93\Delta Pr$	$<0.90\Delta Pr$	$>1.06\Delta Pr$
Flow rate, Q	0.94Qr to 1.06Qr	0.90Qr to <0.94Qr	<0.90Qr	>1.06Qr

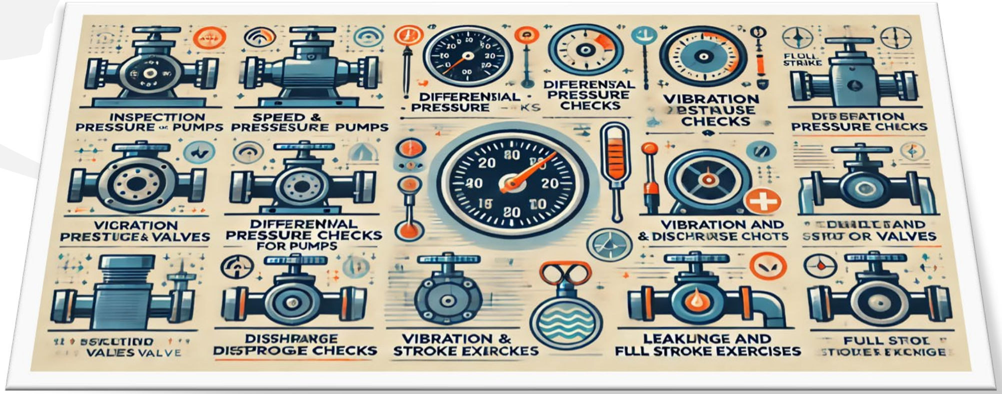
* ΔPr and Qr are the baseline values or reference values

Performing inspections as described supports a Condition-Based Maintenance (CBM) approach, utilizing condition-monitoring tools. Overhaul maintenance, involving comprehensive inspection, repair, and replacement, is recommended every 3 to 5 years or up to 10 years for standby pumps. This includes disassembly, inspection, and replacement of critical components to restore optimal working condition.

- **Valves**

In-service test parameters for valves

Valve type	Testing Requirements	Frequency
Active pneumatically operated valves	Leakage testing Stroke testing Position indication testing	Every 3 month
Active motor-operated valves	Leakage testing Stroke testing Position indication testing	Every 3 month
Manual valves	Full stroke exercise Position indication testing	Every 2 years
Check valves	Leakage testing	Every 2 years
Pressure relief devices	Leakage testing Position indication testing	Every 5 years



Inspection and Maintenance Intervals:

- **UPS systems**

Frequency of maintenance for VLA batteries

VLA battery	Monthly	Quarterly	Annually
Visual inspection of battery	X	X	X
Environmental inspection	X	X	X
Ambient temperature	X	X	X
Detailed inspection of battery		X	X
String float voltage	X	X	X
String float current	X	X	X
Pilot cell float voltage	X	X	X
Pilot cell electrolyte temperature	X	X	X
Individual cell float voltage		X	X
Cell electrolyte temperature (10%)			X
Specific gravity			X
Intercell connection resistance			X
Internal ohmic measurement			X
System load testing			X

Frequency of maintenance for VRLA batteries

VRLA battery	Monthly	Quarterly	Annually
Visual inspection of battery	X	X	X
Environmental inspection	X	X	X
Ambient temperature	X	X	X
String float voltage	X	X	X
String float current	X	X	X
Pilot cell/unit float voltage	X	X	X
Individual cell/unit float voltage		X	X
Individual cell/unit temperature		X	X
Intercell connection resistance			X
Internal ohmic measurement		X	X
AC ripple current and voltage	X	X	X
System load testing			X

- **Switches and switchgears**:

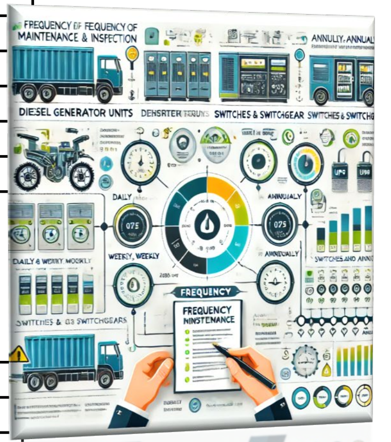
Frequency of maintenance of switches and switchgears

Maintenance	Periodicity
Infrared thermography	6-12 months
Visual inspection	6-12 months
Cleaning	12-36 months
Lubrication	12-36 months
Mechanical servicing	12-36 months
Electrical testing	12-36 months

- **Diesel generator units**:

Diesel drive assemblies periodic tests

Test	Periodicity		
	Quarterly	18-24 Month	10 Years
Slow start	X		
Load run	X		
SIAS and LOOP		X	
Largest-load rejection		X	
Design-load rejection		X	
Endurance and load margin		X	
Hot restart		X	
Synchronizing		X	
Protective trip bypass		X	
Test mode override		X	
Independence			X

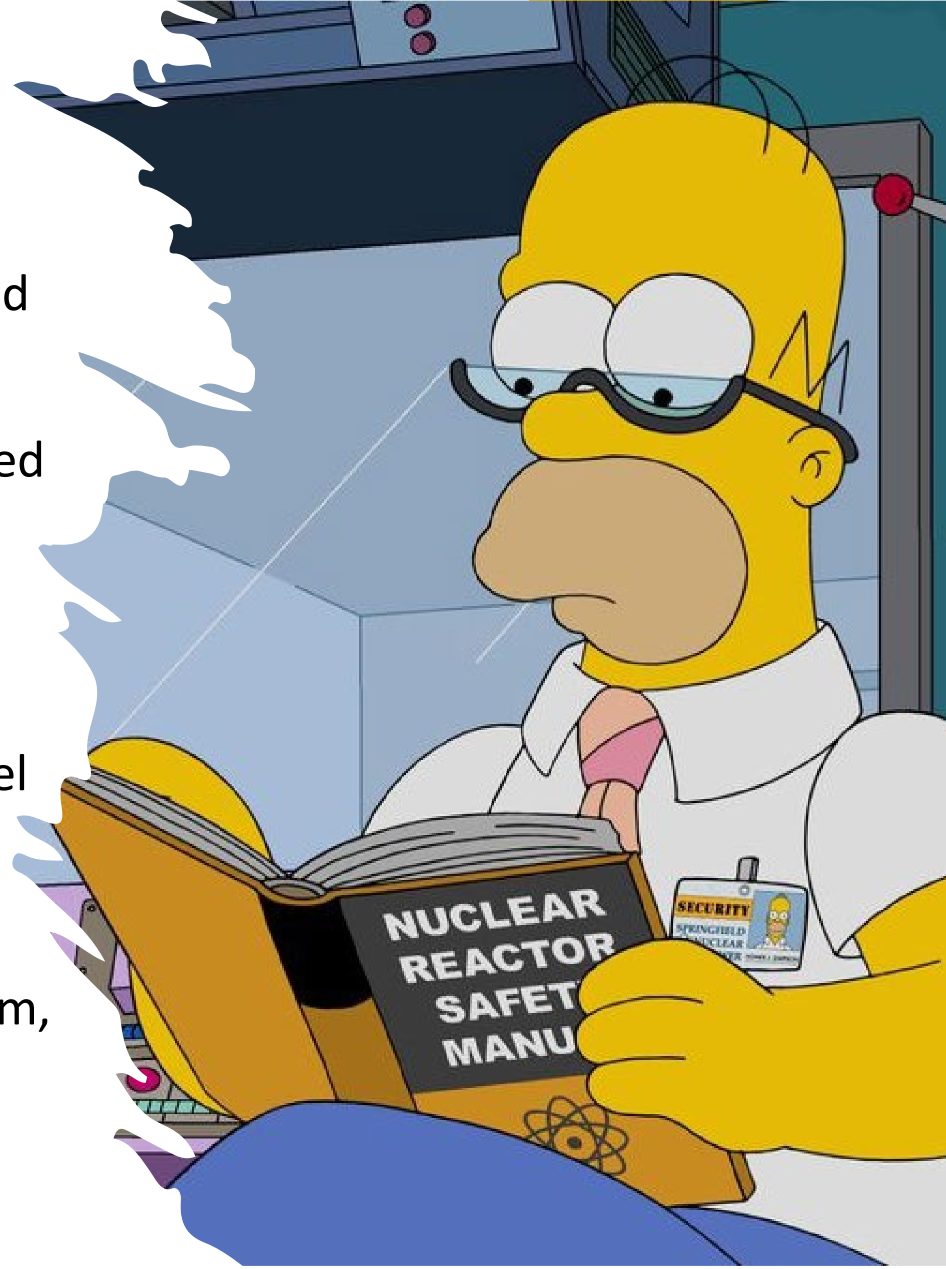


Summary and Conclusions:

This Work comprehensively addresses safety classification and quality requirements for key Structures, Systems, and Components (SSCs) within the NBSR as outlined in the updated Final Safety Analysis Report (FSAR).

The evaluation focuses on SSCs essential for the NBSR's operational functionality and the protection of NIST personnel and the public from potential radiological releases.

To ensure the safety and reliability of the reactor safety system, a rigorous schedule of inspection and maintenance was preposed based on nuclear industry standards.



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