

Safety Requirements for Research Reactors

W. Kennedy
Research Reactor Safety Section
Division of Nuclear Installation Safety



IAEA

International Atomic Energy Agency

SSR-3: Safety of Research Reactors

SSR-3, *Safety of Research Reactors*:

- Provide a basis for safety of research reactors and subcritical assemblies;
- Provide a basis for safety assessment at all stages in the lifetime of a RR;
- Establish requirements related to regulatory control, the management of safety, site evaluation, design, operation and decommissioning;
- Emphasis is placed on the safety requirements that shall be met rather than on the ways in which they can be met.
- Includes design extension conditions as a replacement for beyond design basis accidents.



IAEA Safety Standards
for protecting people and the environment

Safety of
Research Reactors

Specific Safety Requirements
No. SSR-3



Safety Analysis Report - SAR

- Prepared by the operating organization for the justification of the site and design and it is the basis for the safe operation of the reactor.
- The main document for licensing the reactor and is an important link between the operating organization and regulatory body.
- Production of SAR begins as early as possible in the RR project. Updates to the SAR are anticipated as the project proceeds.
- The amount of information provided will correspond to the project stage under assessment, but should be sufficient to allow for making decision on the acceptability of the reactor for that stage.
- It should be reviewed and approved by the regulatory body before the RR project is authorized to progress to the next stage.

Site Evaluation

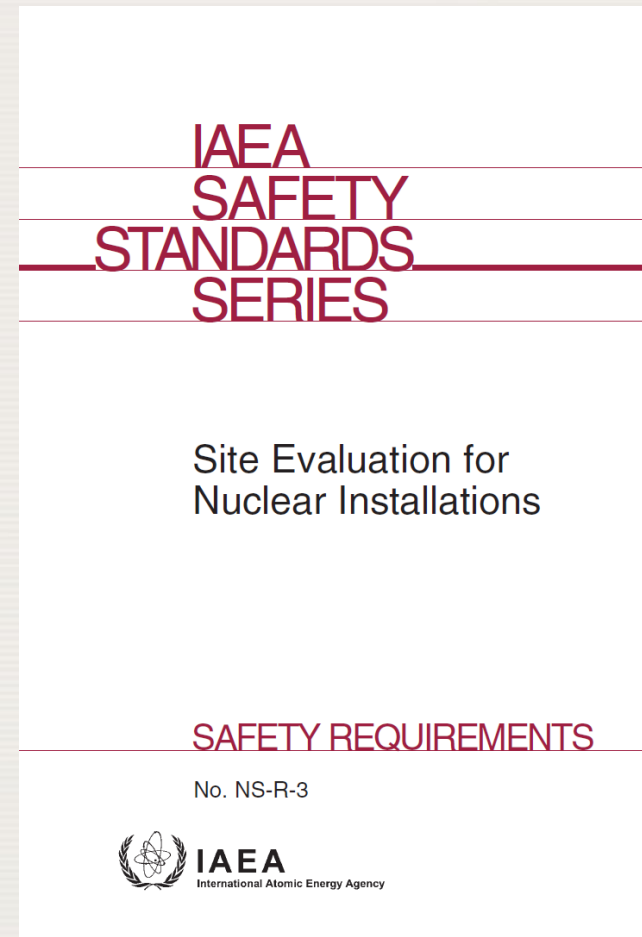
Main safety objective of initial evaluation:



Protection of
public and
environment



Site
characteristics
and external
events



Design

- Defence in depth:
 - Shall be applied to provide enveloped protection against various transients resulting from equipment failure, human errors, internal and external events.
 - The following aspects shall be considered in the design:
 - Provision of successive physical barriers to prevent the release of radioactive material;
 - Use of conservative design margins and implementation of an integrated management system and surveillance activities;
 - Application of the single failure criteria to ensure the fulfilment of the basic safety functions;
 - Use of on-site and off-site emergency plans to mitigate the consequences.

Design

- General requirements for design:
 - Classification of systems, structures and components (SSCs): Shall be according to their functions and safety significance.
 - Codes and Standards for SSCs: Shall be identified and their use shall be in accordance with their classification.
 - Design Basis:
 - Design for operational states and accident conditions (postulated initiating events (PIEs), including design extension conditions (DEC).
 - Design for Reliability: redundancy, diversity, fail-safe, independence, and ease of testing and maintenance.

Design

- General requirements for design:
 - Design for Commissioning
 - Provision for inspection, testing, and maintenance
 - Design for decommissioning
 - Human factors and ergonomic considerations
 - Provisions for utilization and modification
 - Material selection and ageing
 - Provisions for extended shutdown
 - Safety analysis

Design: Specific requirements

- **Reactivity control**

- Sufficient negative reactivity shall be available, considering experiments.
- Maximum rate of reactivity insertion shall be specified.

- **Shutdown system**

- Effectiveness, speed of action, and shutdown margin
- One or more manual initiation for emergency shutdown
- No single failure shall be capable of preventing safety actions
- For computer based digital systems, verification and validation of software shall be performed

- **Reactor protection system**

- Automatic and independent.
- Initiate protective action for the full range of PIEs;
- Protective actions once initiated can not be prevented and shall be completed.
- Shall not be self re-setting
- The design should employ redundancy, independency, and fail safe criteria
- All components shall be functionally tested
- Specific requirements for computer based protection system are also established

Design: Specific requirements

- **Coolant and related systems**

- To provide adequate cooling with acceptable and demonstrated margin;
- Attention shall be paid to prevent core uncover (penetrations above core level, siphon breakers);
- Coolant boundary design to facilitate in-service inspection;
- Redundant flappers;
- Reliable cooling after shutdown;
- Shall provide long term, reliable heat transfer from the fuel to the ultimate heat sink;
- Provisions to monitor and control coolant properties (pH, conductivity).

- **Means of confinement**

- To ensure that a release of radioactive material following an accident does not exceed acceptable limits
- Provisions to enable initial and periodic performance tests to check air leakage of the ventilation system shall be included in the design
- Provision shall be made as appropriate for in situ periodic testing of the efficiency of filters.

Design: Specific requirements

• Experimental devices

- Shall be designed so that they will not affect the safety of the reactor in operational state.
- Safety analysis should be performed.
- If the device is interconnected with the protection system, the interaction should be assessed.
- Monitoring of the parameters of the experiments and the experimental devices.
- OLCs for the experimental devices shall be incorporated into the OLCs for the reactor.

• Instrumentation and control

- Sufficient instrumentation for monitoring reactor operation and process systems. Appropriate controls (manual and automatic). Monitoring following anticipated operational occurrences and design basis accidents (DBAs).
- Ergonomic principles to reduce possibility of human errors.
- For computer based I&C, verification, validation and testing of software shall be provided.
- For safety analysis, conservative values shall be considered for the reliability of the system.
- Audio and visual alarm systems.

Design: Specific requirements

- **Radiation protection systems:** to ensure adequate monitoring in operational states and accident conditions, including DEC, as appropriate.
- **Fuel handling and storage:**
 - Provisions to prevent criticality, permits periodic inspection, permit storage of damaged fuel, provide for physical security, radiation protection, and for controlling the chemistry of the storage media.
 - Provisions to unload the core safely at all times

Specific requirements for other systems are also established:

- Electric power supply;
- Radioactive waste systems;
- Buildings and structures;
- Auxiliary systems.

Operation

- **Organizational provision:**

- Overall responsibility for safety remains with the OO
- OO shall assign the direct responsibility and authority for safe operation to the reactor manager.
- Appropriate management structure shall be established with clear lines of communication, functions, responsibilities for the key positions
- Staff positions to be licensed shall be defined and necessary training should be provided (reactor manager, shift supervisors, operators should be licensed).

- **Safety committee(s):**

- One or more safety committees shall be established to advise the reactor management on safety of the operation and utilization of the reactor. One of these committees shall advise the reactor manager.
- Members of such committees shall be experts in different fields associated with the operation and design of the reactor.
- In particular, safety committee review the adequacy of safety of proposed changes, modifications, experiments, documentations, and provide the reactor manager with recommendations for actions.

Operation

- **Training, retraining, and qualification**

- Formal training and retraining programmes shall be established for the operating personnel, and the experimenters.
- Training should include fundamental knowledge, facility specific-knowledge, and on-the-job training.
- Re-training shall be provided to enhance the knowledge and abilities of the operating personnel.
- Procedures shall be in place to validate the training and to verify its effectiveness and the qualifications of the staff.

- **OLCs:**

- Set of OLCS shall be established. It shall include safety limits, safety system settings, limiting conditions for safe operation, surveillance requirements, and administrative requirements.
- OLCs shall provide the framework for the safe operation.
- Their selection shall be based on the SAR, design, safety analysis, aspects related to the conduct of operation.
- Shall be revised periodically to present the actual status of the reactor.

Operation

- **Commissioning:**

- Adequate commissioning programme for the reactor, experimental devices, experiments, and modifications having major safety significance.
- The commissioning programme shall establish organization and responsibilities, stages, schedule, reports and records, management system for commissioning and treatment of deficiencies and deviations.
- Before implemented, the programme shall be assessed and reviewed by the safety committee and the regulatory.

- **Operating procedures:**

- Shall be developed by the operating personnel in cooperation with the designer/supplier for all safety related operations (commissioning, operation, maintenance, testing, radiation protection, emergencies, etc.).
- Should be prepared in accordance with the management system and be useful in observance of the OLCs.
- Shall be reviewed periodically to allow for incorporating the experience feedback.
- Personnel shall be trained in the use of the procedures.

Operation

- Maintenance, periodic testing, and inspection:

- Shall be conducted to ensure that the SSCs are functioning in accordance to design intents and in compliance with the OLCS.
- Documented programme based on the SAR. Shall be periodically reviewed.
- Frequency of periodic testing and inspection shall be adjusted on the basis of experience.
- Shall be performed according to approved procedures.
- System of Work permit shall be used.
- Results shall be assessed to verify compliance with OLCs.

- Core management and fuel handling

- Core management shall be used to produce safe operational cores consistent with the needs of experiments.
- Fuel procurement, and utilization (burn-up) shall be in accordance with the OLCs.
- Appropriate locations of fuel and core components shall be determined by validated methods and calculations tools.
- Failed fuel shall be identified, and unloaded.
- Fuel handling shall be performed according to approved procedures
- Records on fuel parameters and core configurations shall be kept.

Operation

- **Emergency planning**

- Emergency plan shall cover all activities planned to be carried out in case of emergency.
- Emergency procedures shall be based on the accidents analysed in SAR and those additionally postulated for emergency planning purposes.
- Equipment, facilities, tools, documents, and communication systems used in emergency shall be kept available and well maintained.
- Emergency exercises shall be conducted at suitable intervals. Results shall be reviewed and the lessons learned are used to revise the plan.

- **Records and reports**

- All information related to design, commissioning, operation, and utilization shall be kept. This information includes site data, design spec., as-built drawings, log-books, modification records, operating and maintenance manuals, management system documents.
- Procedures, in accordance with the management system, shall be developed for the generation, collection, retention, and archiving of records and documents.

Operation

- **Utilization and modification**

- Utilization and modification projects shall be implemented following approved procedures.
- Projects shall be categorized according to the safety significance.
- Experiments and modifications with major safety significance shall be subject to safety analysis and procedures for design, installation, commissioning similar to those applied for the reactor itself.
- Proposals shall be reviewed according to approved procedures.

- **Radiation protection**

- In all operational states, the main aim of radiation protection is to avoid unnecessary exposure and to keep doses below dose constraints and as low as reasonably achievable.
- Radiation protection programme shall be established in accordance with regulatory requirements.
- Programme shall include, inter alia, measures for: ensuring cooperation between the staff, providing for decontamination of personnel, equipment, and structure, detecting any radioactivity release, recording radioactive sources inventory, providing adequate training in radiation protection, and for update on basis of experience.

Operation

- **Safety assessment**

- Comprehensive periodic safety review will fulfil the requirements on safety re-assessments.
- On the basis of the results, necessary corrective actions shall consider making modifications to enhance safety.
- Periodic safety review shall cover aspects related to the ageing management.
- Peer reviews.

- **Extended shutdown:** Appropriate measures shall be taken during extended shutdown:

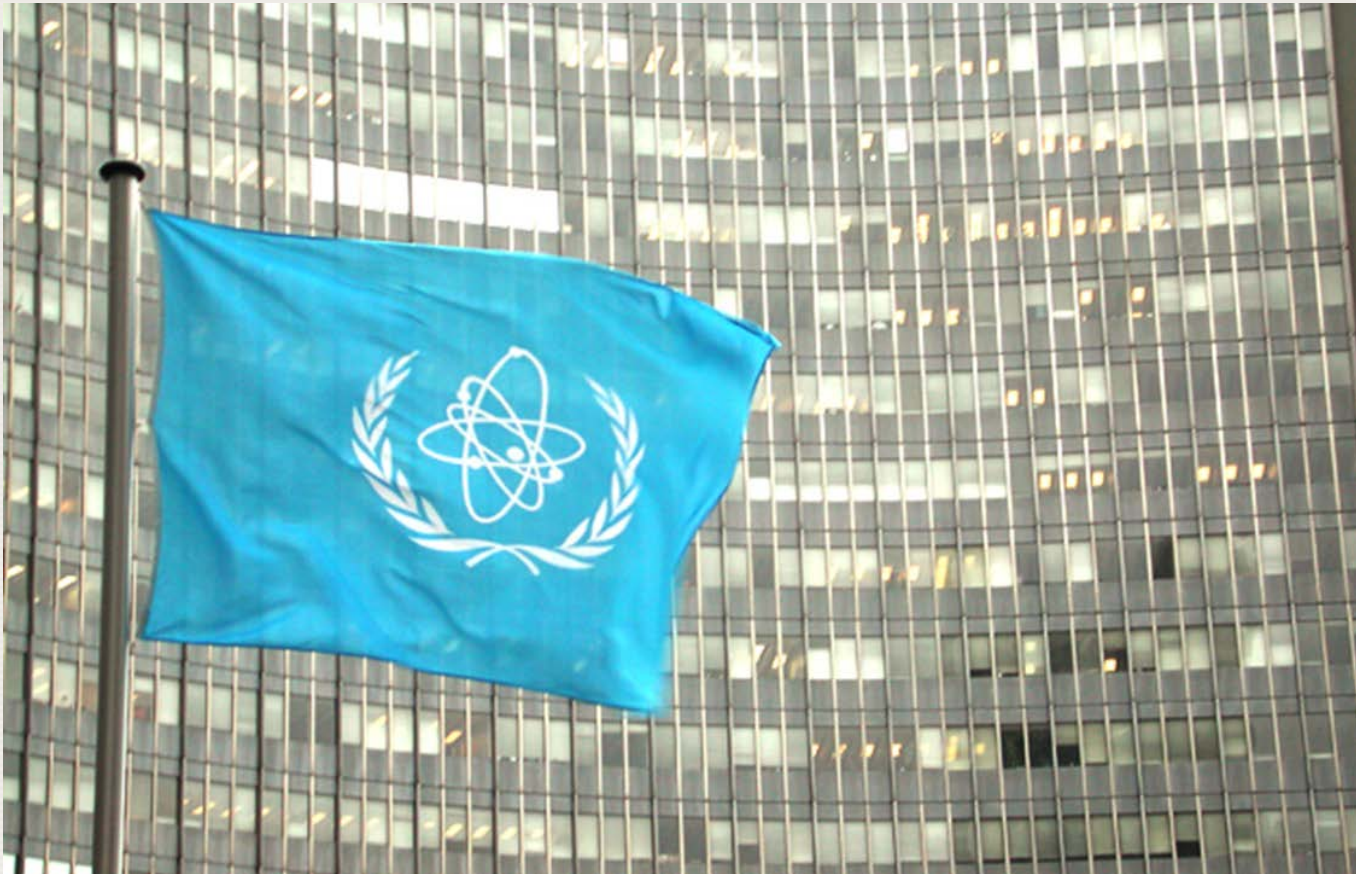
- Unloading the fuel from the core and ensures Subcriticality;
- Revising the OLCs;
- Revising the maintenance, periodic testing and inspection programme
- Implementing measures to prevent acceleration of corrosion;
- Removing components for proactive storage;
- Retaining adequate staff in the facility.

Decommissioning

- Decommissioning shall be considered in all phases of RRs life time.
- **For operating RRs:** all operational activities (including inspections, maintenance, modifications and experiments, etc.) shall be conducted in such away to facilitate their decommissioning.
- Decommissioning plan shall be prepared to ensure safety throughout the decommissioning processes. It shall be reviewed by the safety committee and be approved regulatory body.
- Decommissioning plan shall include evaluation of one or more decommissioning approaches.
- Preliminary decommissioning plan shall be included in the SAR. It should be revised through the reactor life time to account for the technology advances in the field.

Selected postulated initiated events

- Loss of electrical power supplies
- Insertion of excess reactivity
- Loss of flow
- Loss of coolant
- Erroneous handling or failure of equipment or components
- Special internal events
- External events
- Human errors



Thank you for your attention.