NS-R-4: Safety Requirements for Research Reactors

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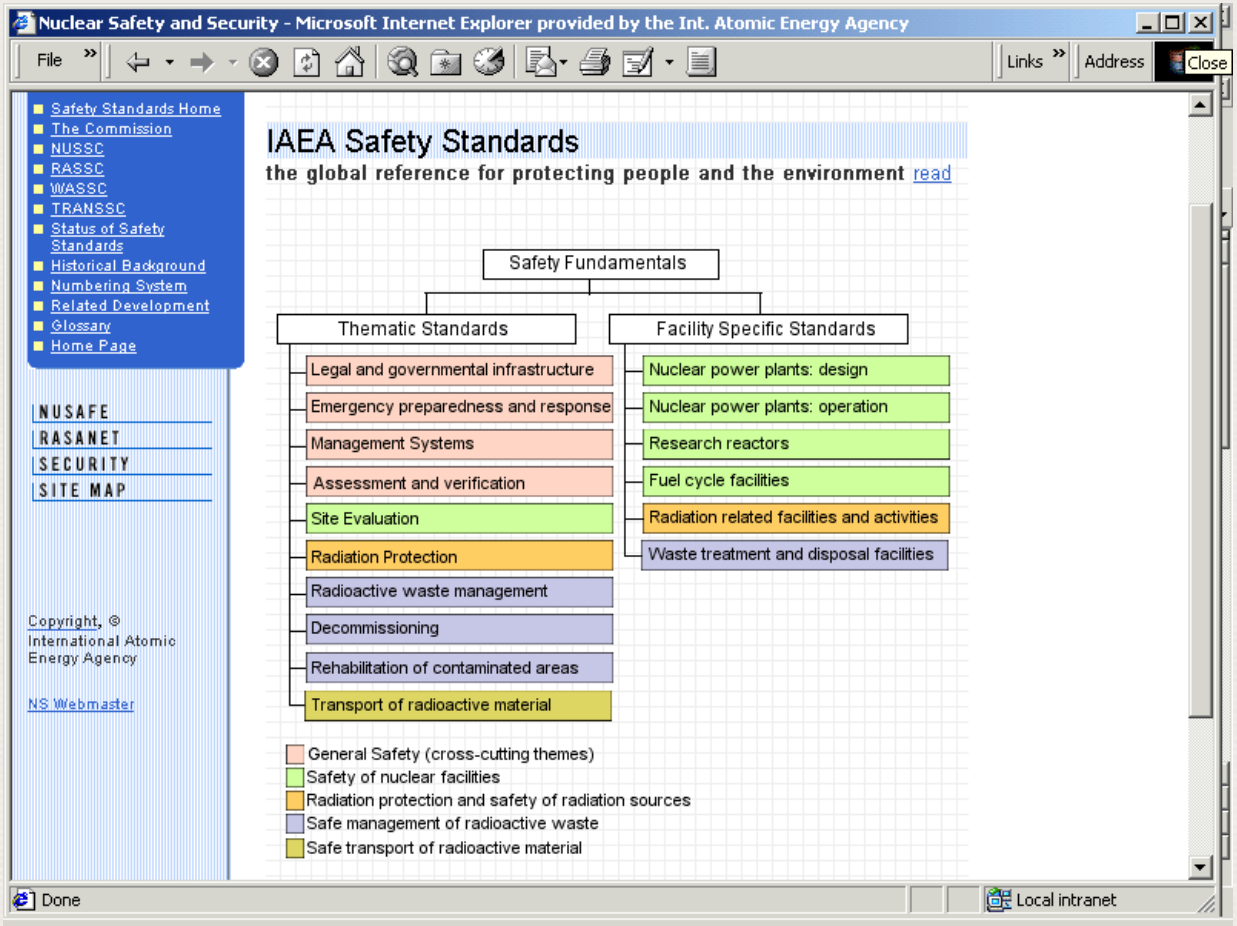
International Atomic Energy Agency

Introduction



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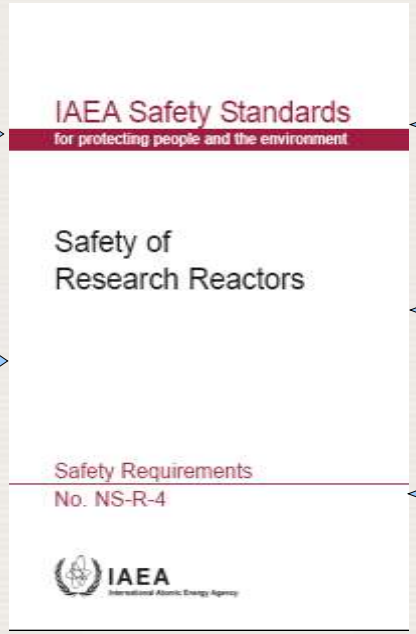
Introduction:
NS-R-4- Safety of Research Reactors

DESIGN

OPERATION

DECOMM.



Regulatory Supervision

Management and Verification of Safety

Site Evaluation

RRs with power levels in excess of several tens of MWs, fast reactors, and reactors using experimental devices such as HPTL or cold neutron source may require application of standards of NPP or additional safety measures.

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Introduction

OBJECTIVES

- To give the safety basis and the basis for the safety assessment;
- Emphasis is placed on the safety requirements that shall be met rather than on the ways in which they can be met.

EXCLUDED

Sub critical facilities
Prototype NPPs
Desalination plants
Naval reactors
Electricity production reactors
Prototype reactors

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Graded Approach: Why Grading?

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Graded Approach: variables to be considered

- ✓ Reactor power;
- ✓ Radiological source term;
- ✓ Amount and enrichment of fissile and fissionable material;
- ✓ Spent fuel elements, high-pressure systems, heating systems, storage of flammables;
- ✓ Type of fuel elements;
- ✓ Type and mass of moderator, reflector, coolant;
- ✓ Amount and rate of reactivity that can be introduced;
- ✓ Reactivity control;
- ✓ Quality of containment/confinement;
- ✓ Utilization (experimental devices, tests, experiments);
- ✓ Siting;
- ✓ Proximity to population.

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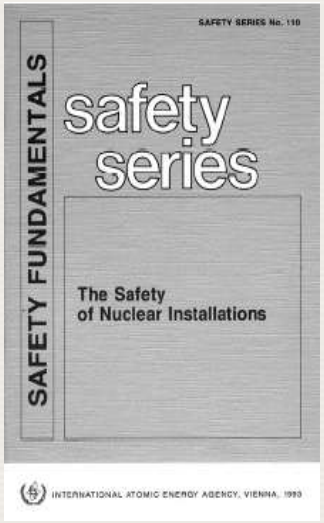
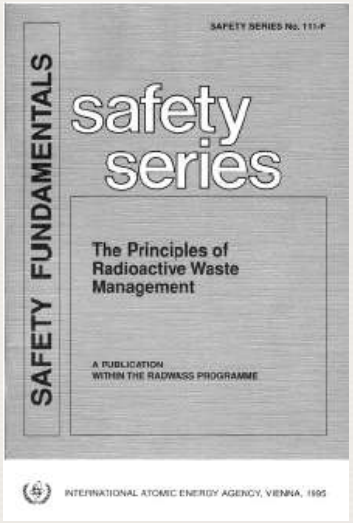
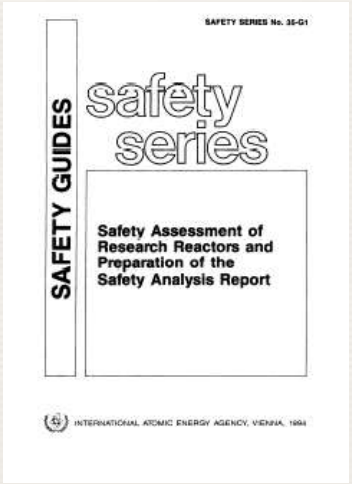
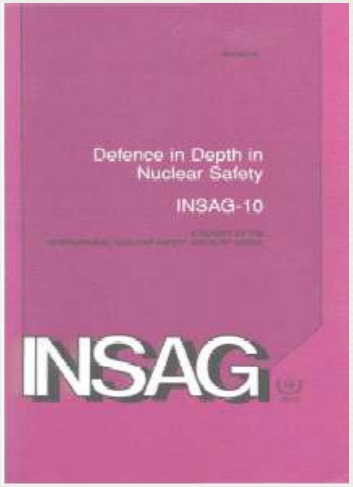
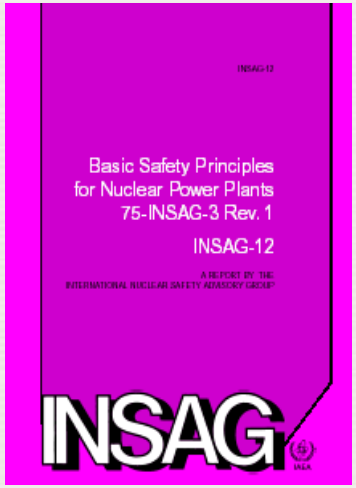
Safety Objectives, Concepts and Principles











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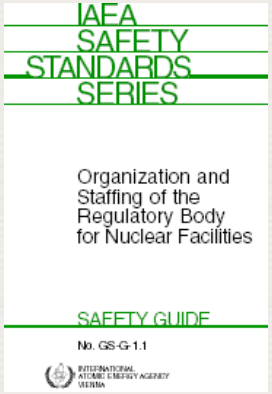
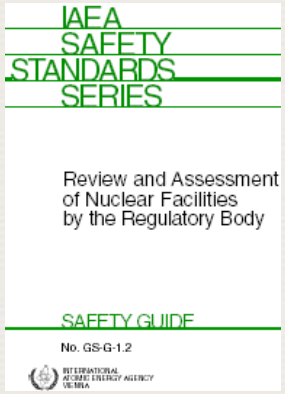
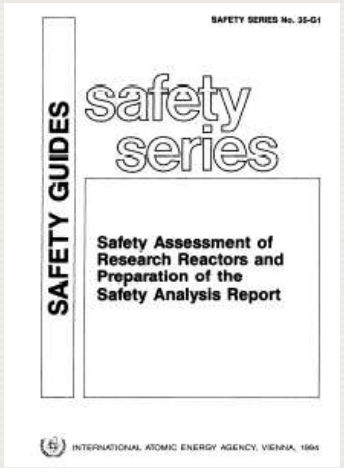
Regulatory Supervision







Emphasis was placed in licensing research reactors

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Licensing Process

- Major stages of the licensing process of research reactors include:
    - Site evaluation;
    - Design and construction;
    - Commissioning;
    - Operation;
    - Modifications;
    - Decommissioning.

Safety Analysis Report - SAR

- Prepared by operating organization for the justification of the site and design and it is the basis for the safe operation of the reactor.
- It is the main document for licensing the reactor and is important link between the operating organization and regulatory body.
- Production of SAR begins as early as possible in the RR project. Successive updates of SAR are anticipated as project proceeds.
- The amount of information provided will be corresponding 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 assessed by regulatory body before the RR project is authorized to progress to the next stage.

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Management and Verification of Safety (1/2)

- Responsibilities of the Operating Organization
- Integrated Management System
- Safety Committees:
  - One or more safety committees, independent of the reactor manager, shall be established to advise the operating organization on the safety of the reactor operation and utilization.
  - One of these committees should advise the reactor manager.
  - Committee members shall be experts in different fields associated with the design and operation of the reactor.
  - The Committee functions, authority, composition, and terms of reference should be documented.

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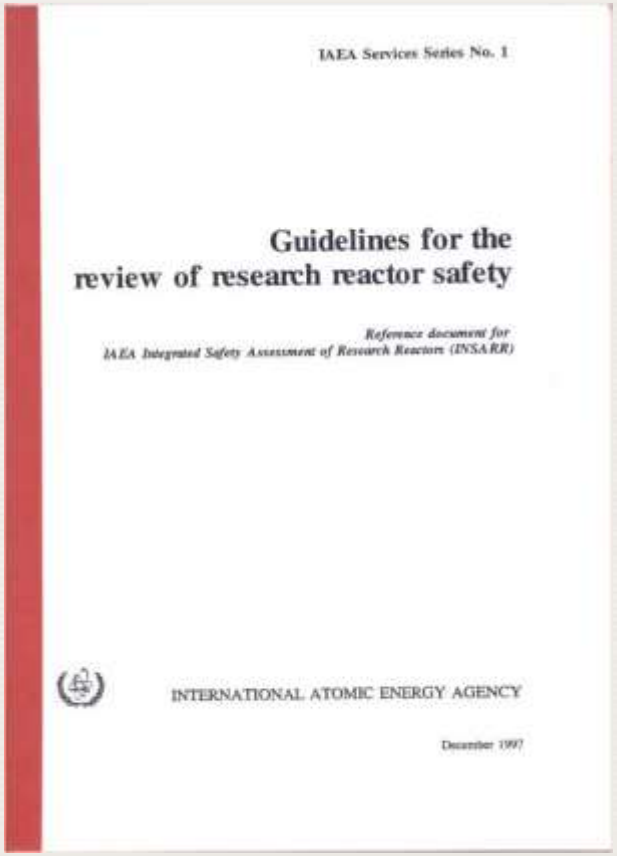
Management and Verification of Safety (2/2)

- Self-assessment and Peer Reviews should be performed to identify and solve safety issues as well as to enhance safety.



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Site Evaluation

Assessment of site characteristics and associated external and internal hazards

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Design (1/7)

- **Defence in depth:**
  - *Shall be applied to provide enveloped protection against various transients resulting from equipment failure, human errors, internal and external events.*
  - *Following aspects shall be considered in the design:*
    - Provision of successive physical barriers to the radioactive material release;
    - Use of conservative design margins and implementation of QA programme 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 (2/7)

- **General requirements for design:**
  - Classification of Structures, Systems and Components (SSCs): according to their functions and safety significance;
  - Identification of Codes and Standards and their use in accordance with the SSCs classification;
  - Identification of the PIEs and the design for operational states and accident conditions;
  - Design for Reliability: Redundancy, Diversity, Fail safe design, independence, and ease of testing and maintenance of SSCs.

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Design (3/7)

General Design Requirements for:

- Commissioning;
- Inspection, testing, and maintenance;
- Decommissioning;
- Human factors and ergonomic considerations;
- Utilization and modification;
- Material selection and ageing;
- Extended shutdown.

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Design (4/7): Specific requirements

Reactivity control

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

Shutdown system

- Speed of action, and shutdown margin
- Provision of one or more manual initiation for emergency shutdown
- No single failure shall be capable of preventing safety actions
- Verification and validation of software shall be performed for computer based digital systems.

Reactor protection system

- Shall be Automatic and independent.
- Shall Initiate protective action for the full range of PIEs; These protective actions once initiated can not be prevented and shall be completed.
- Shall not be self re-setting
- Shall be reliable (redundancy, independency, and fail safe)
- All components shall be functionally tested

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Design (5/7): Specific requirements

Coolant and related systems

- Adequate cooling shall be ensured with acceptable and demonstrated margin;
- Core uncovering shall be avoided (e.g. penetrations above core level, use of siphon breakers);
- The design of the coolant boundary shall facilitate in-service inspection;
- Redundant flappers shall be installed to ensure reliable cooling after shutdown;
- Coolant properties (pH, conductivity) shall be monitored and controlled.

Means of confinement

- Release of radioactive material following an accident shall not exceed acceptable limits;
- Provisions to enable initial and periodic performance tests of the ventilation system shall be included in the design;
- Provision shall be made for in situ periodic testing of the efficiency of filters.

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Design (6/7): Specific requirements

Experimental devices

- Shall be designed so that they will not affect the safety of the reactor in operational state.
- Safety analysis shall be performed for the experiments.
- 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 shall be ensured.
- OLCs for the experimental devices shall be incorporated into the OLCs for the reactor

Instrumentation and control

- Sufficient instrumentation shall be installed for monitoring reactor operation and process systems.
- Ergonomic principles shall be incorporated to reduce possibility of human errors
- For computer based I&C, verification, validation and testing of software shall be provided
- Audio and visual alarm systems shall be installed.

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Design (7/7): Specific requirements

Radiation protection systems:

Shall be installed to ensure adequate monitoring in operational states, DBAs, and as practicable, BDBAs.

Fuel handling and storage:

- Provisions shall be implemented to prevent criticality, to perform periodic inspection, to permit storage of damaged fuel, to provide for physical security, radiation protection and for controlling the chemistry of the storage media.
- Provisions shall be implemented 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.

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Operation(1/7)

Organizational provisions:

- Overall responsibility for safety shall remain with the Operating Organization (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 and 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 advice 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.

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Operation(2/7)

Training, retraining, and qualification

- Formal training and retraining programmes shall be established for the operating personnel, and the experimenters.
- Training shall 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.
- OLCs' selection shall be based on the SAR and aspects related to the conduct of operation.
- OLCs shall be revised periodically to present the actual status of the reactor.

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Operation(3/7)

Commissioning:

- Adequate commissioning programme shall be established for the reactor, experimental devices, experiments, and modifications having major safety significance;
- The commissioning programme shall establish organization and responsibilities, commissioning stages and schedule. Commissioning results shall be documented according to QA programme for commissioning;
- Before its implementation, the commissioning programme shall be assessed and reviewed by the safety committee and the regulatory body.

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.;
- Shall be prepared in accordance with the QA and shall ensure the compliance with the OLCs;
- Shall be reviewed periodically to allow for incorporating the experience feedback;
- Operating personnel shall be trained in the use of the procedures.

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Operation(4/7)

Maintenance, periodic testing, and inspection programmes:

- Shall be conducted to ensure that the SSCs are functioning in accordance to design intents and in compliance with the OLCs;
- 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.

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Operation(5/7)

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 be used to revise the emergency plan.

Records and reports

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

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Operation(6/7)

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 for experiments and modifications shall be reviewed according to approved procedures.

Radiation protection

- Radiation protection programme shall be established in accordance with regulatory requirements;
- Radiation protection programme shall include, inter alia, measures for detecting any radioactivity release, for radiation and contamination monitoring, for decontamination and for recording radioactive sources inventory as well as for providing adequate training in radiation protection.

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Operation(7/7)

Safety assessment

- Periodic safety reviews and peer reviews shall be performed at appropriate intervals and shall cover aspects related to the ageing management. These reviews should conclude on the acceptability for continued operation of the facility from the safety point of view.

Extended shutdown:

Appropriate measures shall be taken during extended shutdown. These include:

- Unloading of the fuel from the core to ensure sub-criticality;
- Revising the OLCs;
- Revising the maintenance, periodic testing and inspection programme;
- Implementing measures to prevent acceleration of corrosion;
- Retaining adequate staff in the facility.

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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 a way to facilitate their decommissioning.
- Decommissioning plan shall be prepared to ensure safety throughout the decommissioning process. It shall be reviewed by the safety committee and approved by the 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.

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Appendix :
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.

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Annex I:
Selected safety functions (examples)

• Buildings and structures	• To form a barrier against the uncontrolled release of radioactive material to the environment; • To provide protection against external and internal events to the enclosed safety systems; • To provide shielding against radiation.
• Reactor core	• To maintain fuel geometry and necessary coolant flow path in order to ensure shutdown and heat removal during all operational states of the reactor and DBAs; • To provide negative reactivity feedback; • To provide a means of moderating and controlling neutron fluxes.

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Annex II: EXAMPLES OF OPERATIONAL ASPECTS OF RRs THAT REQUIRE PARTICULAR ATTENTION

- REACTIVITY AND CRITICALITY MANAGEMENT
- CORE THERMAL SAFETY
- SAFETY OF EXPERIMENTAL DEVICES
- REACTOR MODIFICATION
- COMPONENT AND MATERIAL MANIPULATIONS
- HUMAN SURVEILLANCE

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Thank you for your attention!

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