Safety Analysis for Research Reactors: Methods and Approaches

H. Abou Yehia
Research Reactor Safety Section
Division of Nuclear Installation Safety

IAEA
International Atomic Energy Agency

Outline

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- **Safety Analysis Methods**

- **Safety Analysis Types**

- **Performance of Safety Analysis:**
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  - Evaluation of event sequences;
  - Evaluation of event consequences;
  - Comparison against acceptance criteria.

- **IAEA Publications on safety analysis for research reactors**

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Safety analysis – Introduction

- An acceptable safety analysis should demonstrate that the three basic safety functions are fulfilled;

- The analysis should identify the Design Basis Accidents (DBAs) and the Beyond Design Basis accidents (BDBAs) for the purpose of establishing acceptance criteria;

- PIEs are unintended events that directly or indirectly challenge the basic safety functions. Such events necessitate protective actions to prevent or mitigate undesired consequences.

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Safety analysis – Introduction

- **The results of the safety analysis are used for:**

    - The determination of the OLCs;
    - Development of the periodic testing and inspection programmes;
    - Development of the operating procedures;
    - Emergency planning;
    - Justification of proposals for modifications and experiments.

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Safety analysis methods

- The well accepted approach for safety analysis for research reactors is to consider credible PIEs and then apply deterministic methods to estimate the maximum possible releases to the environment.

- The results are compared against acceptance criteria established (or agreed by) the regulatory body.

- Safety analysis for research reactor is mainly performed using deterministic methods, which ensure conservatism for the safety demonstration.

Safety analysis methods

- **In the deterministic methods:**

  - Conservative or bounding data are used;
  - Most unfavourable reactor configuration (e.g. beginning of operation, etc..) is considered;
  - Uncertainties associated with the parameter that affects the variable of interest are considered;
  - Actions by operators are considered not to be taken for a prescribed period of time.

- The probabilistic methods may be used to complement deterministic methods. The probabilistic methods may be used to:

  - Evaluate which accident sequence is of a greater likelihood;

  - Identify hidden weakness in the design;

  - Quantify the value of possible improvements.

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Safety analysis: Types

Safety analysis for design:

- Used to support the design of a new reactor or modification to an existing one and to confirm that the design meets the relevant safety requirements;

- Iterative process between the design and safety performance;

- Accounts for all the challenges that the reactor may expect during its lifetime are considered;

- Used in setting characteristics such as equipment sizing, OLCs, dose to public and operator.

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Safety analysis: Types

Safety analysis for licensing:

- To demonstrate that facility design features and the selected OLCs ensure that no credible accident should lead to unacceptable radiological consequences; and to demonstrate compliance with regulatory requirements.

- Proceeds in parallel with the design process. The scope and level of details increases as design progresses. The final analysis should reflect the as-built facility.

Safety analysis for supporting emergency planning:

- Describes the reactor behaviour in BDBAs. The results of BDBAs, defining the source term and radiological releases, could also be used for emergency planning.

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Performance of safety analysis for Research Reactors

Steps:

- Identification and selection of PIEs;
- Evaluation of event sequences;
- Evaluation of event consequences;
- Comparison against acceptance criteria.

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Identification and selection of PIEs

Methods for identifications of PIEs include:

- Fault trees;

- Identification of failure modes and events that lead to these failures;

- Operating experience from the facility or from other similar facilities, use of the IAEA-IRSRR database;

- Comparison with the List of PIEs from the IAEA Safety Standards.

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Identification and Selection of PIEs

- To simplify the safety analysis it is reasonable to group all PIEs into categories;

- For each category, the event that would be limiting should be determined for further analysis;

- Selection of the limiting events can be based on more detailed calculations, qualitative comparisons with other events, or engineering judgement.

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Identification and selection of PIEs

PIEs Categories(NS-R-4):

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

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Evaluation of event sequences

- **For every PIE: Determination of:**

  - *The contributors (occurrences which lead to this event);*
  - *Sequence of event and reactor system operation:*

    - Significant occurrences on time scale;
    - Indication of correct/incorrect functioning of reactor protection system, instrumentation;
    - Evaluation of dependant failures;
    - Required operator actions, etc.

- **Rules for the analysis:**

  To ensure that the systems response are applied uniformly in the analysis. They constitute accident sequence, and determine the sequences that are outside the design basis and thus excluded from further analysis.

Evaluation of event sequences

Calculations:

- Use of qualified computational methods and tools;
- Identification of the input parameters and initial conditions used for the analysis;
- Results of the analysis including values of the key parameters as a function of time during the course of the transient;
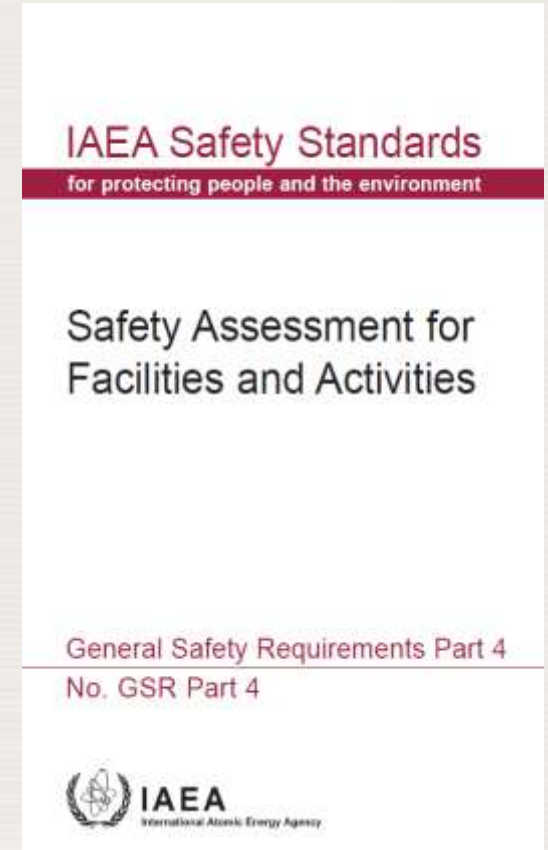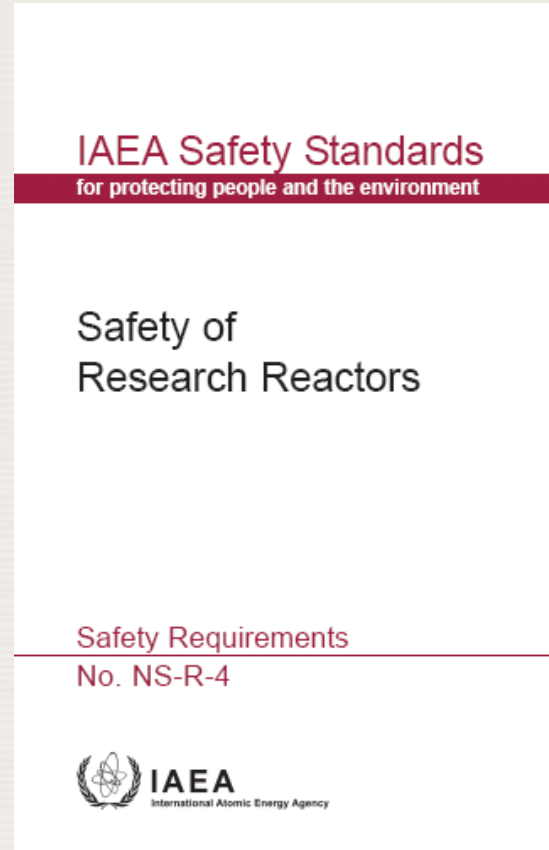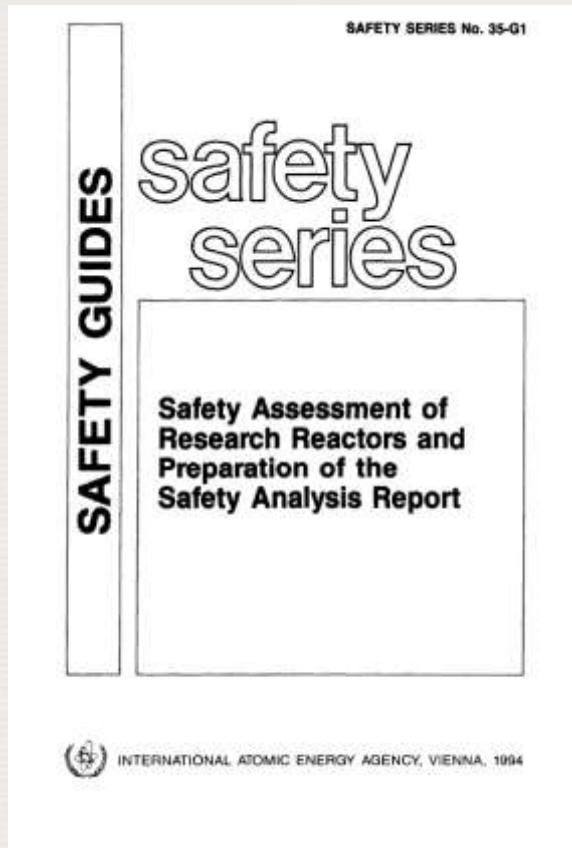- Determination of damage states.

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Evaluation of event consequences

- Estimation of the radiological consequences of the events that are bounding (or limiting) for each category.

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Comparison against acceptance criteria

- The results of the safety analysis should be compared against pre-established acceptance criteria.

- Acceptance criteria may be basic or specific:

    - *Examples of basic acceptance criteria are the maximum allowed dose to the public or prevention of fuel cladding failure;*

    - *Specific acceptance criteria are used to include additional margins beyond the basic criteria, such as:*
        - Maximum cladding temperature lower than certain value;
        - Maximum heat flux not exceeding the CHF or onset of significant void.

- Acceptance criteria are specified (or agreed) by the regulatory body.

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IAEA publications on safety analysis for RRs

SAFETY SERIES No. 35-G1

SAFETY GUIDES

safety series

Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1994

IAEA Safety Standards
for protecting people and the environment

Safety of Research Reactors

Safety Requirements
No. NS-R-4

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IAEA Safety Standards
for protecting people and the environment

Safety Assessment for Facilities and Activities

General Safety Requirements Part 4
No. GSR Part 4

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IAEA Safety Report # 55

- Presents a set of suggested methods and practices on performing safety analysis for research reactors (including modifications).

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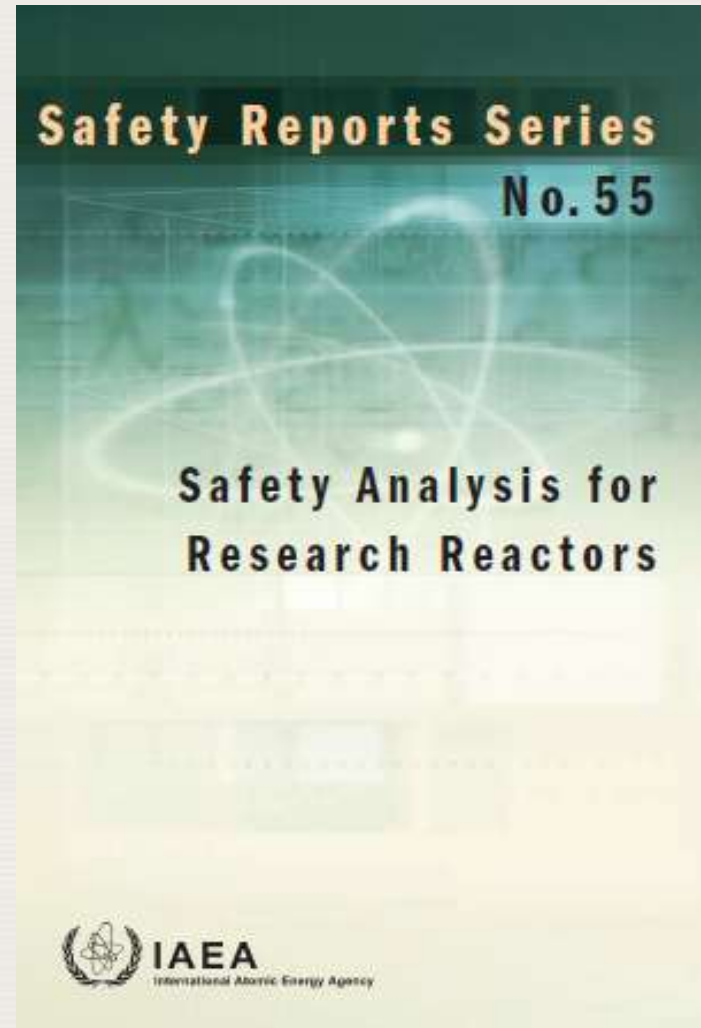
Thank you for your attention!

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