Nuclear Data at IRSN: From safety assessment to research

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IRSN presentation

- A public body with industrial and commercial activities, placed under the joint authority of the Ministries of Defense, Environment, Energy, Research, and Health.

- National public expert for research and technical support on radiation protection and nuclear safety risks

- 1800 employees, including more than 1000 specialists: researchers, Ph.D. students, post-docs and engineers

- A budget of €280 million, with 40% devoted to research
Three main missions

- Research and services of public interest, including public transparency.
- Support and technical assistance to the public authorities for civil or defense-related activities.
- Contractual assessment, study and measurement services for public and private organizations, both French and foreign
Institutional environment

- Designers and constructors
- Operator
- Parliament
- Public authorities
- Stakeholders (CLIs)
- THE PUBLIC
- IRSN, Public assessment
- Research into risks
- Public assessment
- Public authorities
- ASN, ASND
- Supreme Committee for Transparency and Information on Nuclear Safety - HCTISN
What is the interest of IRSN for ND?

Example of the criticality-safety assessment

The strategy to overcome the criticality risk is to define some provisions allowing to ensure the respect of subcritical limits (mass, geometry, fissile concentration, etc.)

These subcritical limits are mostly based on calculations and are determined by an acceptability criterion, such as:

\[ 1 - \Delta k_{\text{eff}_{\text{admin}}} \geq k_{\text{eff}_{\text{calc}}} + 3\sigma_{\text{calc}} + \Delta k_{\text{bias}} \]

- \( \Delta k_{\text{eff}_{\text{admin}}} \): administrative margin
- \( \Delta k_{\text{bias}} \geq 0 \): calculation bias if there is a trend to underpredict \( k_{\text{eff}_{\text{calc}}} \)
- \( \Delta k_{\text{bias}} = \Delta k_{\text{ND}} + \Delta k_{\text{scheme}} \)
What is the interest of IRSN for ND?
Example of the criticality-safety assessment

Assessment of the criticality-safety provisions is an important part of the safety evaluation, but assessment of the criticality calculations is also another important part since there is no measurement of the $K_{eff}$ in fuel cycle facilities and in transport packages ($\neq$ reactor cores)

The safety margin may be significantly reduced (or even disappear) if the « real » $K_{eff}$ is underpredicted due to a bad estimates of the uncertainties

The uncertainties come mainly from model description, ND libraries and calculation schemes
What is the interest of IRSN for ND? Example of the criticality-safety assessment

Uncertainties due to the model and the calculation scheme can be mastered by using:
- bounding assumptions (for tolerance fabrication, etc.) and a rigorous QA procedure for the creation of the input deck,
- reference codes such as continuous energy MC codes.

But, uncertainties due to ND libraries need a thorough knowledge of ND, in particular the covariance matrices.
What is the interest of IRSN for ND?
Example of the criticality-safety assessment

- Another specific issue related to criticality safety is the broad range of materials, configurations and neutron spectra that is not covered by reactor physics applications.

- In general (and it is quite understandable), a great deal of effort is devoted to nuclear reactors, but less to criticality safety.

- Nevertheless, there is a need of knowledge *a minima* since a criticality accident may lead to fatalities.

A relevant criticality-safety assessment requires a good knowledge of Nuclear data (out of other issues) regarding their possible impact on the safety margins.
IRSN’s research activities on ND
Example of the criticality-safety assessment

Determination of the $\Delta k_{\text{bias}}$ in two steps:

1. Selection of representative integral experiments
   Engineers experience, specific tools (sensitivity analysis, etc.)

2. Calculation of a $\Delta k_{\text{bias}}$ on the basis of the selected experiments
   Average of C-E values or more sophisticated statistical methods

Methods such as GLLSM require covariance data
IRSN’s research activities on ND
Example of the criticality-safety assessment

To have a better knowledge of the impact of ND on the safety margins, IRSN chose to focus on:

1. Tools to determine $\Delta k_{\text{bias}}$ according to different methodologies (MACSENS)

2. Enhancing the quality of ND of interest by
   - performing new differential experiments,
   - re-evaluating ND of interest, including covariance data,
   - processing of ND,
   - validating them vs. Integral experiments.
IRSN’s research activities on ND

2 IRSN projects support R&D activities on ND

- **PRINCESS** (Project for IRSN Neutron physics and Criticality Experimental data Supporting Safety)
  - Following the closure of the CEA/Valduc facilities, search for collaborations for integral and differential experiments
  - With US-DOE (in the frame of the NCSP), with JAEA ...

- **INSIDER** (Investigations in Neutronics for contributing to the Safety margin assessment based on data assimilation from Integral and Differential Experiment Researches)
  - To have a better knowledge of Nuclear Data, including covariance matrices
  - To develop methods for estimating biases and uncertainties
IRSN’s research activities on ND

**ND processing tools**
- GAIA 2: a IRSN Nuclear Data processing tool based on NJOY to generate MORET and VESTA code’s libraries and test it’s own evaluations
- Internal format for Monte Carlo applications…

**ND evaluation and validation**
- Evaluation and validation of isotopes of interest ($^{54}$Fe, $^{56}$Fe, $^{95}$Mo, $^{96}$Mo, $^{103}$Rh, Gd, Pb, etc.) ➔ JEFF project
- Nuclear data at low temperature
- Benchmark testing of new libraries

**MACSENS (bias and uncertainties)**
- Statistical methods to determine the $\Delta k_{bias}$
- New methodologies as GLLSM
IRSN’s research activities on ND

Integral experiments

Differential experiments

ND evaluations (JEFF, ENDF, etc.)

ND libraries (covariance matrices)

Simulation tool

Biases and uncertainties tools

Application model

PRINCESS

INSIDER

Benchmarks (ICSBEP, proprietary exp.)

C \pm \delta C, sensitivities

E \pm \delta E

Keff + \Delta \text{kbias}

Scheme

Processing tools (GAIA…)

Differential experiments

Integral experiments

Processing
Final Remarks

- Over the years IRSN has been developing skills and tools for application on criticality safety
- Nuclear data remain a major source of uncertainties
- Nuclear data evaluation and uncertainties rely upon experimental data
- Methodologies for estimating biases and uncertainties
- Tight connections with experimental facilities around the world to help IRSN to address issues on ND and uncertainties
Final Remarks

Nuclear data needs arise in several fields as:

- Source Term of Radiation and Heating
- Decay Heat Calculation
  - Fission Product & Minor Actinide Productions (Fission Product Yield, Activation)
  - Decay Data
- Shielding Calculation for Fuel Cask
  - Neutron and Gamma-ray Productions, (α,n)
- Calculation on Re-criticality Potential in case of severe accident
  - Neutron Production
- LWR Safety
  - Thermal scattering cross sections, S(α,β)
  - Ageing
Thank you for your attention!
Back-up slides
Validation of Nuclear Data
Benchmarks Intercomparison Study: COG, KENO, MCNP, MORET

- New benchmarks intercomparison using various nuclear data libraries
  - JEFF-3.1.1, JEFF-3.3, ENDF/B-VII.1 and ENDF/B-VIII.0
- Use of codes validation suites ➔ independent modeling

Provide a rigorous basis for quality and validating nuclear data libraries

ADVANCE, VaNDaL, ICSBEP/DICE
Validation of Nuclear Data
Benchmarks Intercomparison Study: COG, KENO, MCNP, MORET

- Publication planned