Are Nuclear Data important to the Swiss Regulator?

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Outline

- Situation in Switzerland
- Main activities of ENSI
- Legal Requirements
- Safety assessment
- Examples of the usage of Nuclear Data
    - Decay heat (LOCA rule)
    - Criticality safety in geological repository applications
- Summary

Situation in Switzerland
Reactor Operation / Decommissioning

The Swiss population voted in 2017 for the adoption of the Energy Strategy 2050

- Relevant for the present discussion:
  No replacement of operating nuclear power plant
- NPPs will be operated as long as they can demonstrate their safety
  - KKB, KKG and KKL are expected to operate up to 60 years
  - KKM will be permanently shut down at end of 2019

Situation in Switzerland Geological Repository

Phase 1 and 2 have been completed by 2018

- Government approved reduction from initial 6 sites (phase 1) to 3 sites for extensive site exploration

Geological disposal has entered 3rd phase (2019 – 2029)

- 2029: Government will issue general license for the geological repository (includes selection of the site)
- 2030: Approval by Swiss Parliament
- 2031: Possible public vote

Main activities of ENSI (www.ensi.ch) in the coming years

- Monitoring of safety of operating reactors (KKB, KKG, KKL)
- Monitoring of safety of decommissioning of Mühleberg NPP (KKM)
- Criticality safety of SF storage pool
- Long-term dry storage of SF
- Reviewing of safety cases submitted by the «National Cooperative for the Disposal of Radioactive Waste” (NAGRA)

Legal requirements in Switzerland

- Swiss Nuclear Law stipulates regulation based on current state of the art in science and technology (SST)
- In practice, proven engineering practices and operational experience also form an important basis
- Regulator does not need to execute own research, but must stay knowledgeable on SST in order to effectively review submissions of licensees

Fundamental Safety Functions, Barriers

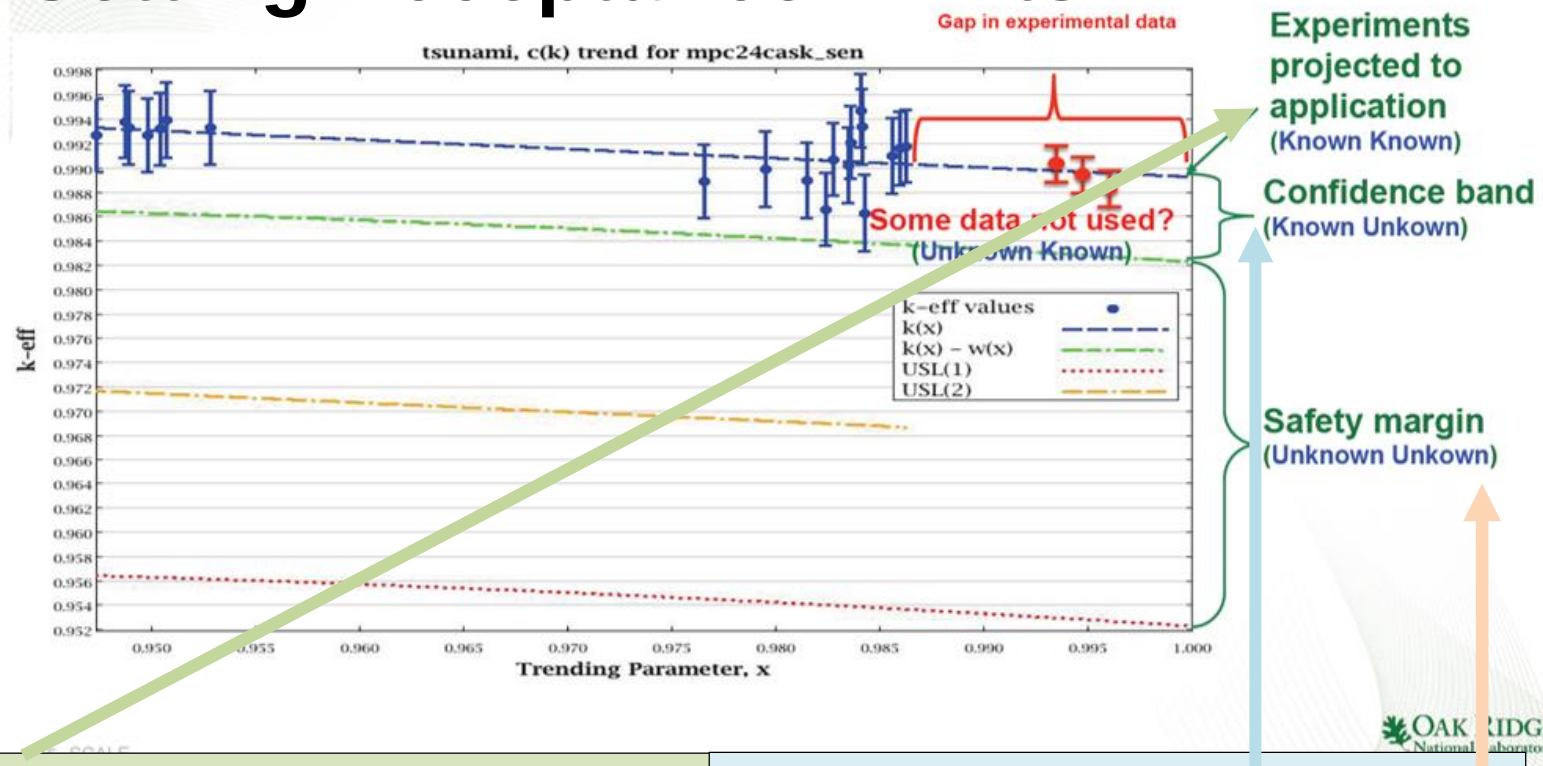
- Reactor Shut-down
  - Needs high quality criticality assessments
- Sub-Criticality
  - SF pools
  - Transport casks
- Coolability
  - level of decay heat
- Containment

Options for safety assessment

- Accurate knowledge enables thorough and reliable assessment of safety
  - Trend towards “Best-estimate plus Uncertainty” (BEPU)
- However, not always feasible if only approximate theories / knowledge are available:
  - Ensure safety by applying adequate safety margins

  → Phenomenology must be well understood
    - **Impact of controlling parameters well understood**

Key business of Regulator: Setting Acceptance Limits



Known Knowns	**Known Unknowns**
Regulator's attention	**Unknown Unknowns**

Examples of ND application from the perspective of a regulator

- Monitoring / licensing of operation of reactor core
- DBA analysis (eg. LOCA, RIA, …)
- Spent fuel pools
- Criticality safety in geological repository
- …

Monitoring of reacator core

- Nuclear data form the basis for any reactor physics calculation
- Acceptance limits for key core parameters depend on nuclear data, new nuclear data
  - maxLHGR and related parameters
  - Reactivity coefficients < 0
- Advanced models (e.g. n-transport,…) have improved quality of core simulations
- ND are already of high quality for LWR-related applications,
  - availability of large amount of validation data
- Hence, ND are not considered by ENSI as a priority item for further development

DBA Analysis - Evolution of LOCA rule (decay heat) 10CFR50-46, App K

- Evolution due to better modeling, availability of better measurements
  - ANSI/ANS 5.1 (1973) : conservative multiplier
  - *ANSI/ANS 5.1 (1979)*
  - *ANSI/ANS 5.1 (1994)*
  - *ANSI/ANS 5.1 (2005)*

ANSI-ANS-5.1 (1979) versus ANSI-ANS-5.1 (1973)

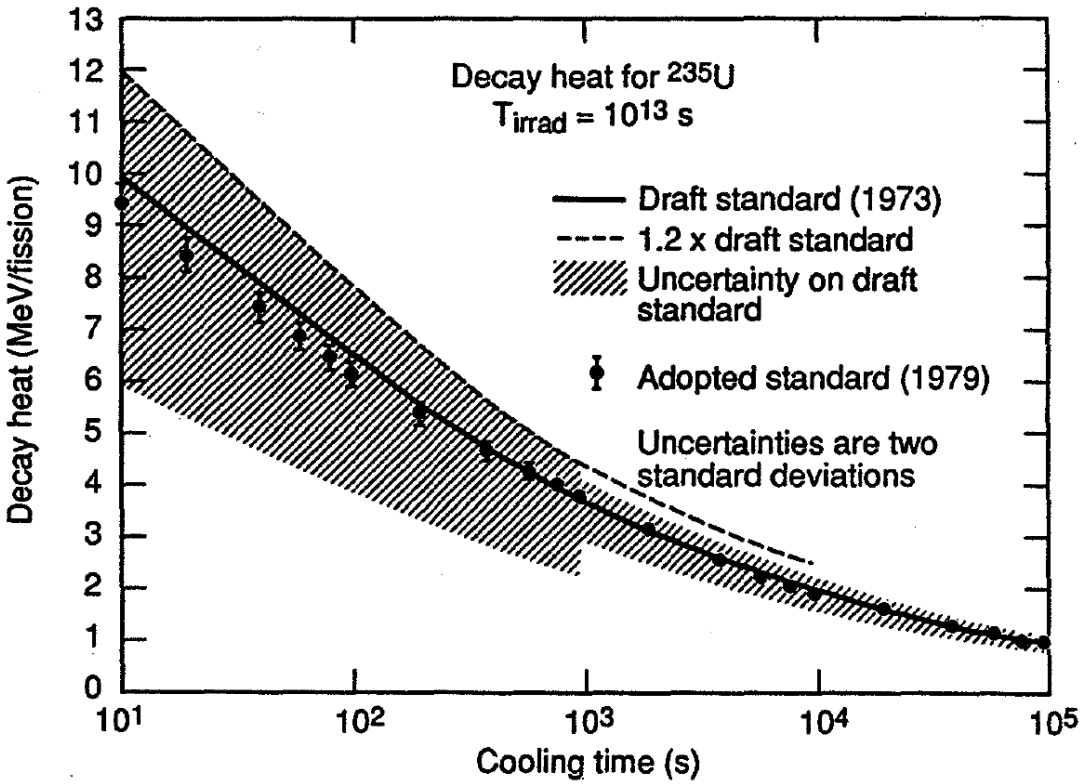
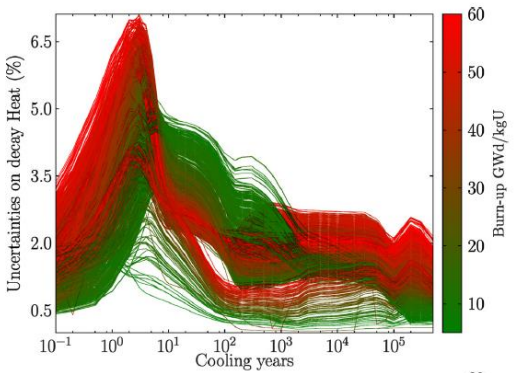


Fig. 6 Decay heat for ^{235}U following an infinite irradiation. —, 1973 draft standard;[1] cross-hatch area indicates uncertainty assigned to that curve. – – –, heat generation rate directed for regulatory process.[3] Data points and error bars represent the 1979 ANSI/ANS-5.1 Decay Heat Standard for ^{235}U and associated two-standard-deviation uncertainties.[8]

J. K. Dickens, T. R. England and R. E. Schenter: «Current Status and Proposed Improvements to the ANSI/ANS-5.1 American National Standard for Decay Heat Power in Light Water Reactors", NUCLEAR SAFETY, Vol. 32, No.2, April-June 1991"

Decay Heat Uncertainty

Nuclear Data



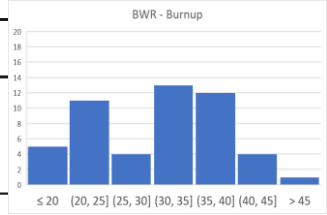
Uncertainties on decay heat due to nuclear data, for three different cores (PWR and BWR). One curve represents one assembly at the end of a specific cycle.

Rochman Dimitri A., et.al.:
«Uncertainties for Swiss LWR spent nuclear fuels due to nuclear data”,
EPJ Nuclear Sci. Technol. 4, 6 (2018).
DOI: 10.1051/epjn/2018005

Validation at CLAB

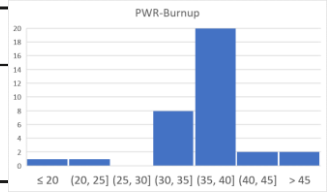
For BWR assemblies the uncertainty will be:

Power (W)	Uncertainty (%)
50	8.4
350	1.8



For PWR assemblies the uncertainty will be:

Power (W)	Uncertainty (%)
250	3.7
900	2.1

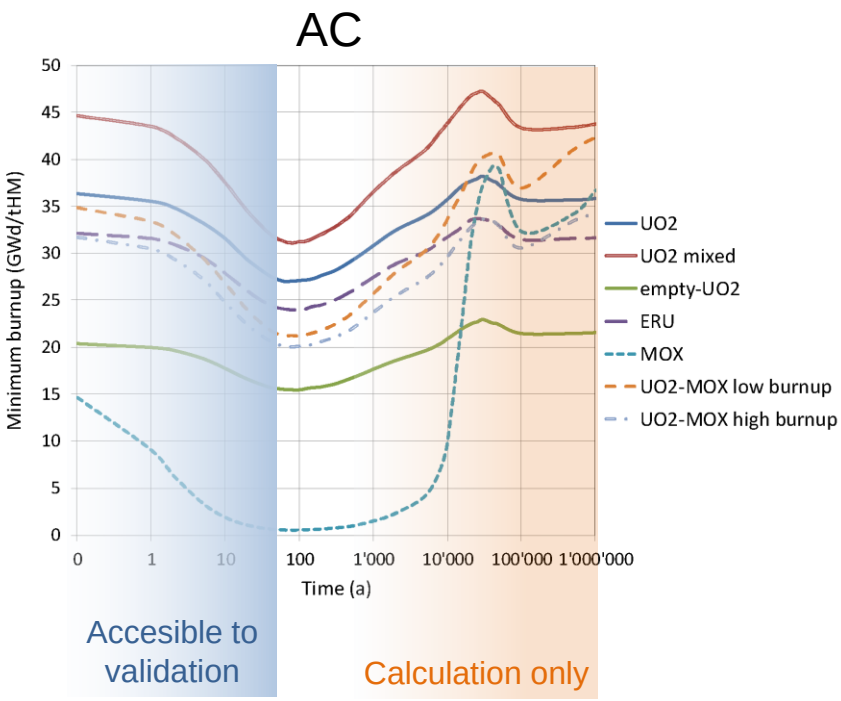


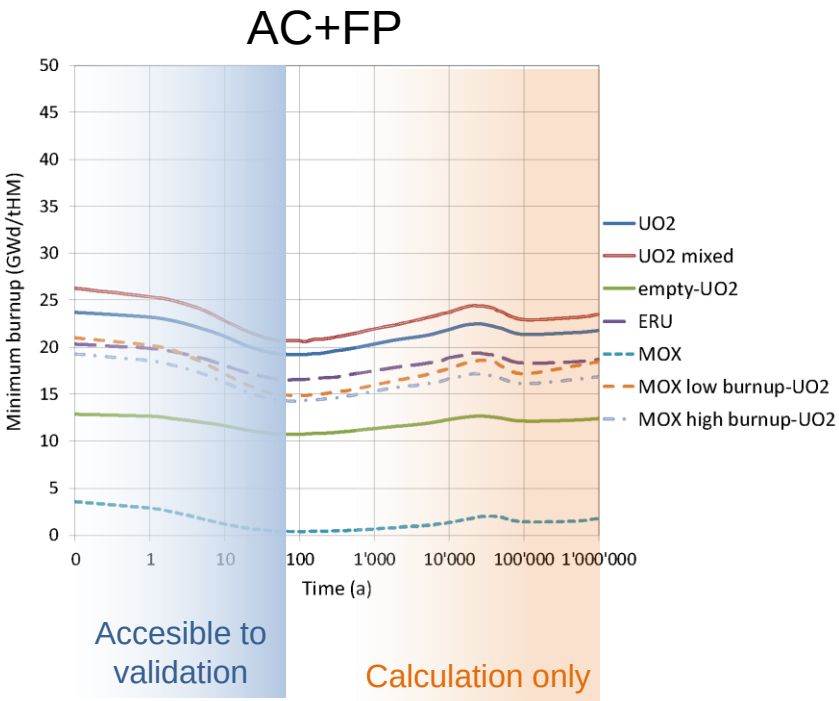
SKB Rapport R-05-62, 2006: Measurements of decay heat in spent nuclear fuel at the Swedish interim storage facility, Clab

Geological repository applications

- Criticality safety must be ensured at all times: $k_{eff} < k_{eff}^{USL}$
- Loading of different FA into the repository containers is therefore constrained

Minimum burnup for FA to be stored in repository container





The evolution of minimum burnup credit required to comply with a *keff* value below 0.95 within the geological disposal timeframe: (**left**) and (**right**)

A. Vasiliev et.al.: Preliminary Assessment of Criticality Safety Constraints for Swiss Spent Nuclear Fuel Loading in Disposal Canisters, *Materials* **2019**, *12*, 494; doi:10.3390/ma12030494

Geological repository applications

- Consideration of burnup-credit with actinides and fission products allows for loading of even 2-cycle FA into the repository containers
- Safety demonstration relies on
  - Calculations with advanced and well validated tools
  - Accessibility to high-quality nuclear data for a very wide range on nuclides
  - much larger than typically employed for monitoring of core operation!!
  - **Quality assurance!**
  - Accounting for uncertainties becomes very important considering the evolution of the nuclide concentrations
  - → **high-quality covariance data**

Summary I

Regulator is focused on nuclear safety

- State-of-the-art of science and technology must be considered for nuclear licensing in Switzerland
- In general, accurate models are very desirable, but not always feasible
- Best-estimate plus uncertainty calculations (BEPU) or conservative approaches are both acceptable

Summary II

To answer the question at the outset of the presentation:

- **Yes**, Swiss Regulator has a genuine interest in accurate and *quality-asssured nuclear data* since they evidently form an imporant basis for ensuring nuclear safety (including geological repositories)
- It is very desirable that nuclear data are as accurate as feasible
  This pertains especially for geological repository applications
- For BEPU, consistent covariance information is very important

Summary III

- Will the Swiss Regulator therefore participate (through his TSO) in future nuclear data related research activities?

→ **Not** actually **planned**

  – Nuclear data represent but one (rather mature) area out of many that are relevant for ensuring nuclear safety

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www.ensi-rat.ch

www.ensi-rat.ch/conseil-de-lifsn/