PAUL SCHERRER INSTITUT

PSI

eurad

European Joint Programme on Radioactive Waste Management

D. Rochman

EURAD WP8/Subtask 2.1: Status

The project leading to this presentation has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 847593.

EURAD WP8 annual meeting, 20-22 October 2021, SCK-CEN, Belgium

Zertifiziertes Managementsystem STARS ISO 9001

Summary

- Subtask 2.1: short recall (what and which participants)
- Current short status for each participants
- Plans/Conclusions

EUropean Joint Programme on RADioactive Waste Management

EURAD

5-year implementation phase 1 – EURAD-1

This project receives funding from the Euratom research and training programme under grant agreement No 847593.

Subtask 2.1: short recall

- Subtask 2.1: Theoretical study of SNF source terms
- Subtask leader: PSI
- Subtask contributors: CIEMAT, JSI, NAGRA, PSI, SCK.CEN, VTT, KIT, JRC-Geel, ENRESA
- Main responsible persons:
  - CIEMAT: Francisco Alvarez
  - JSI: Marjan Kromar
  - NAGRA: Ahmed Shama
  - PSI: Dimitri Rochman
  - SCK.CEN: Luca Fiorito
  - VTT: Silja Häkkinen
  - KIT: Ron Dagan
  - JRC-Geel: Peter Schillebeeckx
  - ENRESA: Ana Muñoz

Subtask 2.1: short recall

- Activities:

1. Select representative assemblies
2. Calculated quantities: isotopic concentrations, decay heat, gamma/neutron emissions
3. Cooling time: up to 1e5 years
4. Perform calculations (nominal and uncertainties/sensitivities/biases)
5. Identify relevant parameters
6. Summary of results
7. Workshop

Subtask 2.1: General view

- (as of today; *in italic*: in progress/not yet reported):

Institute	Code	Samples (**reported**/*planned*)
PSI	CASMO, CASMO/SIMULATE/SNF	GU1, GU3, BM1, *ENRESA, GE, HEDL, "SKB-2006", SKB-50,*
JSI	SERPENT2 ALEPH2 SCALE (TRITON/NEWT) POLARIS DRAGON	S1.PWR, NPP Krško fuel, *SF95-5* *REGAL (SCK)* *SKB-50*
SCK.CEN		
JRC Geel		
KIT	MCNP/CINDER, Nucleonica	*SF95-5*
NAGRA	SCALE (TRITON) POLARIS	*SF95-5, BM1, ENRESA* *Gundremmingen-7 (B23)* "SKB-2006", GE *SKB-50*
VTT	SERPENT2	Gundremmingen-7 (B23)
CIEMAT	EVOLCODE, MCNP/CINDER	*SF95-5*
ENRESA/ENUSA	Define a BWR case (8 PIE) + POLARIS	Report, *ENRESA*

Subtask 2.1: short recall

- Time frame:
- Activities delayed in 2020 and 2021 (+ 1 year) due to COVID and late request for new decay heat values to SKB

	Month 3 (Aug. 2019)	Month 7 (Dec. 2019)	Month 11 (April 2020)	Month 15 (Aug. 2020)	Month ?? (2020-2021)	Month ?? (2021-2022)
Task Definition	PSI					
Simplified calculations		All				
Advanced calculations			All			
Sensitivity				All		
Uncertainties					All	
Report/workshop						PSI

Current status: PSI

- Four samples to be studied (GU1, GU3, BM1, ENRESA)
- Consistent approach (same code, libraries, uncertainties)
- Compared to other institutes
- GU1, GU3: papers published
- BM1: paper accepted
- ENRESA samples: paper under preparation

- Decay heat:
  - calculations done for “SKB-2006”
  - Waiting to access SKB-50

Current status: JSI/SCK.CEN/JRC Geel

- S1.PWR
  - Sensitivity and uncertainty
  - Results are being compiled for publication

- Takahama SF95-4 and SF95-5
  - Based on SF-COMPO, C/E biases, sensitivity, model assumptions
  - Results are being compiled

- REGAL
  - UOX fuel sample FT1X57-D05-BU1, ALEPH-2, Serpent-2 C/E biases, sensitivity and uncertainty, different nuclear data libraries
  - Paper in preparation

- SKB-2006
  - ALEPH-2, Serpent-2, C/E biases, sensitivity and uncertainty, different nuclear data libraries

Current status: KIT

TASK2-1
SF95-5

KIT Dagan

MURE: ENDF 8 , TENDL 2019, ISOMER handling

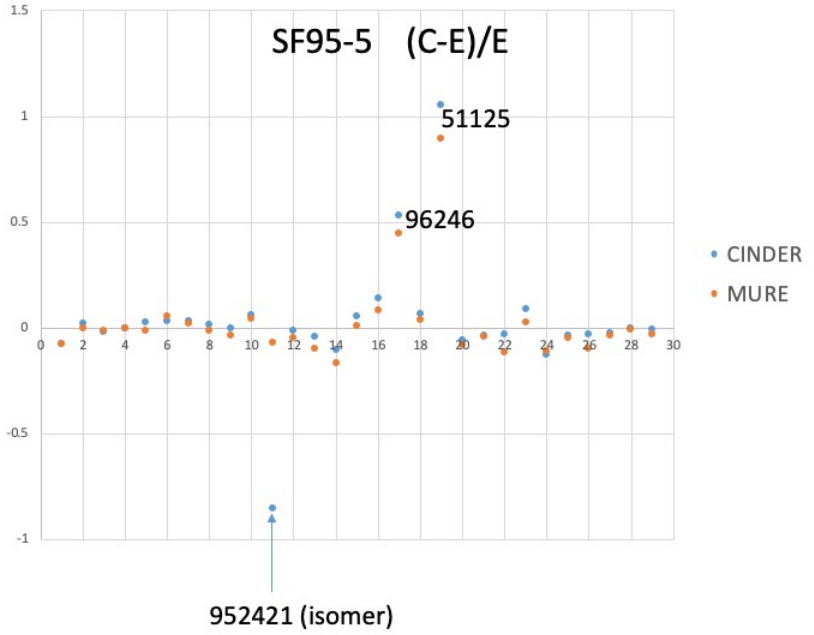
CINDER: ENDF 7.1

- MCNP together with the burn up codes MURE and CINDER
- Different cross sections and different isomer treatment

	C/E-1 MURE	C/E-1 CINDER
922340	-0,07367	-0,078034997
922350	-0,00174	0,018919009
922360	-0,01138	-0,016909715
922380	-0,00041	-0,000685661
942380	-0,01359	0,026138195
942390	0,05359	0,030736909
942400	0,0178	0,029866965
942410	-0,01431	0,0121352
942420	-0,03649	-0,001620392
952410	0,04318	0,062668821
952421	-0,07206	-0,853105364
952430	-0,0489	-0,011032846
962420	-0,09945	-0,040629662
962430	-0,16491	-0,103457558
962440	0,00732	0,054051434
962450	0,08566	0,140962867
962460	0,44673	0,529021777
441060	0,03856	0,067198291
511250	0,89412	1,053087444
551340	-0,08335	-0,059914553
551370	-0,04294	-0,03346486
581440	-0,11787	-0,028795441
631540	0,02603	0,086317364
601420	-0,11182	-0,124931257
601430	-0,04731	-0,035783545
601440	-0,09975	-0,03047211
601450	-0,03455	-0,024668565
601460	-0,01006	-0,002063647
601480	-0,03158	-0,005338437

SF95-5 MURE vs CINDER

Karlsruhe Institute of Technology



Current status: NAGRA

- BM1, SF95-5 and Gundremmingen-7
  - Performed with SCALE/Polaris, isotopic vectors (PIE)
- "SKB-2006"
  - Performed and analyzed

- Paper on decay heat uncertainties published
- Paper on decay heat nominal values accepted
- Paper on decay heat Machine learning to be submitted

- PhD thesis submitted and defense on Oct. 29: analysis of biases in DH and isotopic compositions

DATA-DRIVEN PREDICTIVE MODELS: CALCULATIONAL BIAS IN CHARACTERIZATION OF SPENT NUCLEAR FUEL

Thèse Nº 9309

Présentée le 29 octobre 2021
à la Faculté des sciences de base
Laboratoire de physique des réacteurs et de comportement des systèmes
Programme doctoral en energie

pour l'obtention du grade de Docteur ès Sciences
par

Ahmed Shama

Acceptée sur proposition du jury

Dr S.-R. Cherkaoui, président du jury
Prof. A. Pautz, directeurs de thèse
Dr D. Rochman, directeurs de thèse
Dr G. Ilas, rapporteuse
Dr P. Schillebeeckx, rapporteur
Prof. A. Manera, rapporteuse

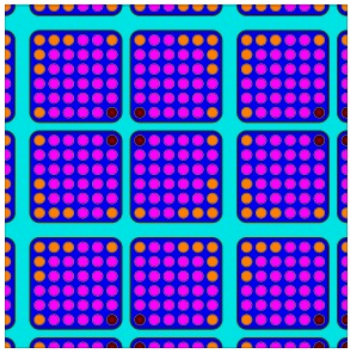
2021

EPFL

Current status: VTT

- Gundremmingen-7 with SERPENT2: work finished

RESEARCH REPORT VTT-R-00631-21

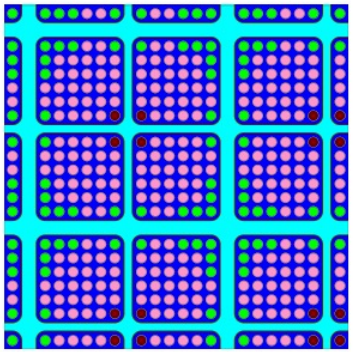


Gundremmingen-A assembly B23 sample I2680 depletion calculation with Serpent 2

Authors: Silja Häkkinen
Confidentiality: Public

VTT

RESEARCH REPORT VTT-R-00632-21



Sensitivity and uncertainty analysis of Gundremmingen-A assembly B23 sample I2680 depletion calculation with Serpent 2

Authors: Silja Häkkinen
Confidentiality: Public

VTT

Current status: VTT

- Gundremmingen-7 with SERPENT2: work finished

Summary

The work described in this report presents simplified and advanced calculations in EU project EURAD work package 8 Spent Fuel Characterization and Evolution Until Disposal (SFC) subtask 2.1. The report presents Serpent 2 depletion calculations of one sample in a 6x6 BWR assembly. The Serpent calculated nuclide concentrations are compared to measured concentrations available in SFCOMPO-2.0. Decay heat of the calculated sample is also examined.

The calculations were performed for a two dimensional and a three dimensional assembly using different nuclear data libraries JEFF-3.2 (and JEFF-3.1.1), ENDF/B-VII.1 and JENDL-4.0. All calculations were repeated three times normalizing the reaction rates to different power densities based on different measurements of sample or assembly burnup. The best correspondence to measurement data was achieved using normalization based on ^{148}Nd NDA measurement of sample burnup. The 3D model agreed with the measurements somewhat better than the 2D model particularly for the calculated plutonium and curium concentrations. One explanation to this is probably more realistic neutron spectrum at sam
istic coolant properties as a function of assembly heigh
10 % between calculations with different nuclear data
differences between 3-6 % are present also for ^{238}Pu an

Both 2D and 3D calculations agreed with the measurem
uncertainties for nuclides ^{148}Nd, and ^{238}U and in the 3D
For the other ten/eight nuclides, differences were larger t
ever, discrepancies in some of the measurement results
not be as accurate as claimed at least for some of the
analysis of the calculated concentrations are conducte
task 2.1.

Summary

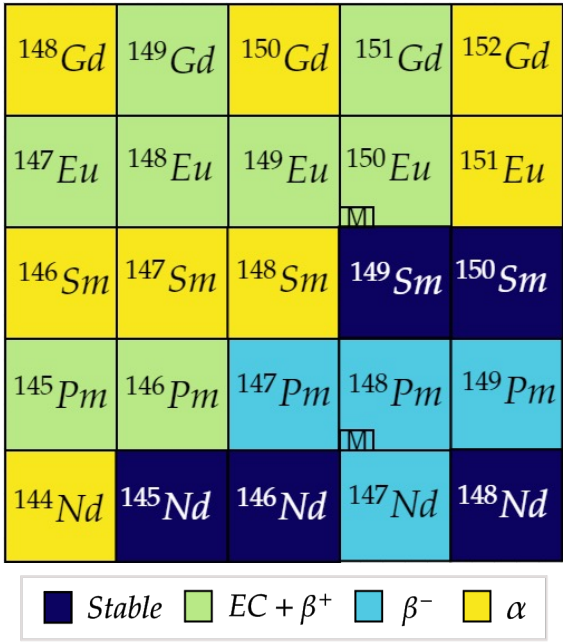
The work described in this report presents sensitivity and uncertainty calculations in EU project EURAD work package 8 Spent Fuel Characterization and Evolution Until Disposal (SFC) subtask 2.1. Sensitivity and uncertainty analysis is performed in Serpent 2 depletion calculations of one sample in a 6x6 BWR assembly. Calculated sensitivites and uncertainties to decay heat and concentrations of several nuclides are presented. The Serpent calculated nuclide concentrations are compared to measured concentrations available in SFCOMPO-2.0.

The calculations were performed on a two dimensional assembly. Sensitivities and uncertainties on several operating history parameters, fuel properties and computational methods were calculated. Uncertainties in burnup were by far the most significant uncertainty component for decay heat and the studied nuclides ^{14}C, ^{36}Cl, ^{137}Cs, ^{148}Nd, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{242}Cm and ^{244}Cm. The only exception was ^{239}Pu that was most sensitive to water density (moderator density and void fraction). Other generally rather significant contributors to uncertainty were water density (moderator density and void fraction) and fuel density. Uncertainties in pin radius or ^{234}U enrichment had small or insignificant impact to the uncertainties of the calculated quantities. Uncertainties in decay data had some impact only on ^{242}Cm concentration and decay heat at 0 cooling time. The impact of the other studied uncertainty components, power density, water and fuel temperature, ^{235}U enrichment and ^{238}U content, were more dependent on the calculated quantity. According to the sensitivity studies fuel swelling, cross section data and fission yield data may have significant impact on many of the calculated quantities.

Current status: CIEMAT

- Takahama-3 SF95 pellet 5 case

  – Paper/report started
  – validated EVOLCODE with the Takahama-3 SF95-5 pellet, using JEFF-3.3, as reference calculation.
  – estimated the uncertainty due to nuclear data (isotopic, decay heat, neutron and gamma emission)
  – sensitivity calculations (library, code, model, geometry)
  – analyzed the differences and have a set of recommendations for JEFF and also for ENDF.



Difference of ~40% between EVOLCODE and MCNP/CINDER:

There is a **lack of branching ratio** data in JEFF-3.3 for **capture in ^{147}Pm** leading to ^{148M}Pm, one of the parents of ^{148}Sm (with a half-life of 41.3 d, larger than the ground ^{148}Pm, with 5.37 d), allowing an extra accumulation of ^{148}Sm with EVOLCODE. MCNP/CINDER has this information in its *cinder.dat* file.

Current status: ENRESA

- ENRESEA delivered the BWR assembly specifications on June 2020,
- Providing an updated report in November 2020
- Performing studies with POLARIS, to be compared with CASMO5 (PSI, Studsvik), end 2021/beginning 2021

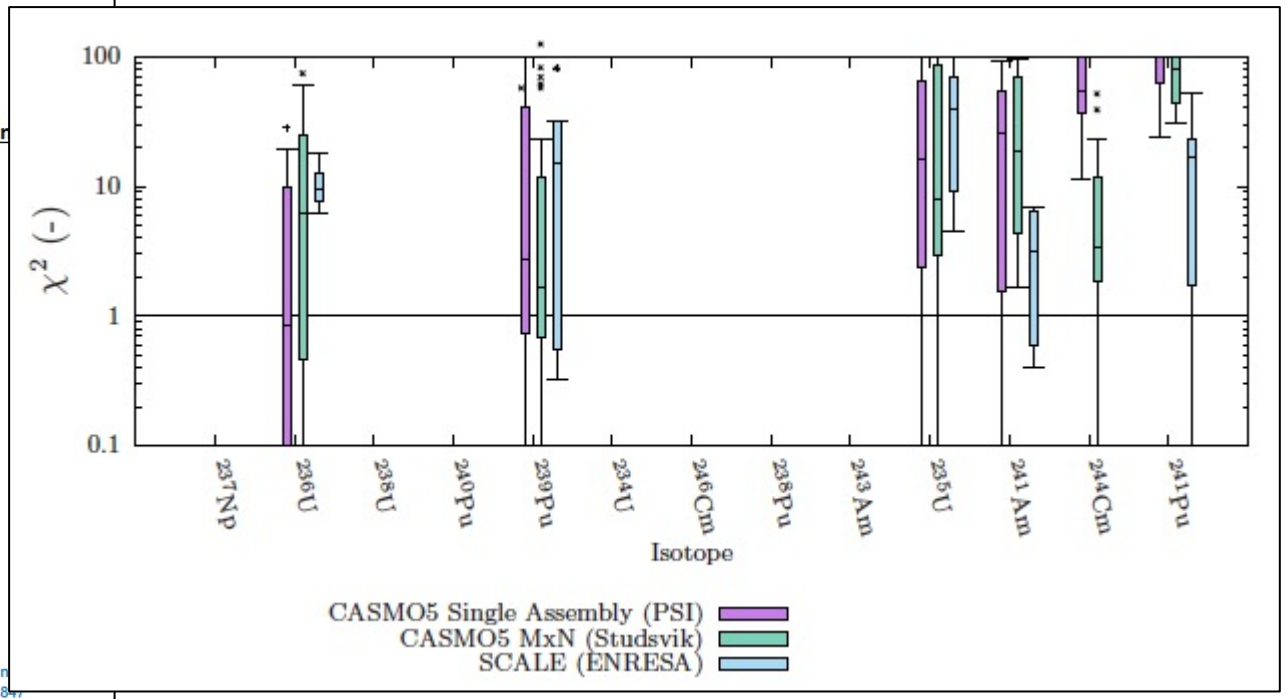
INF-TD-010032 Revision 1

Specification of measured isotopic concentration

of BWR Spent Fuel

26th October 2020

The project leading to this application has received funding from the European Un
2020 research and innovation programme under grant agreement No 84



Plans/conclusions

- All participants have started their calculations and publications
- We follow a delayed schedule (+ 1 year)
- Collection of all results: 2022
- Expected draft report: 2022
- Joint publication: 2023
- Workshop: place and date to be defined in 2022/2023

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Wir schaffen Wissen – heute für morgen