RASTA

Radionuclide Source Term Analysis

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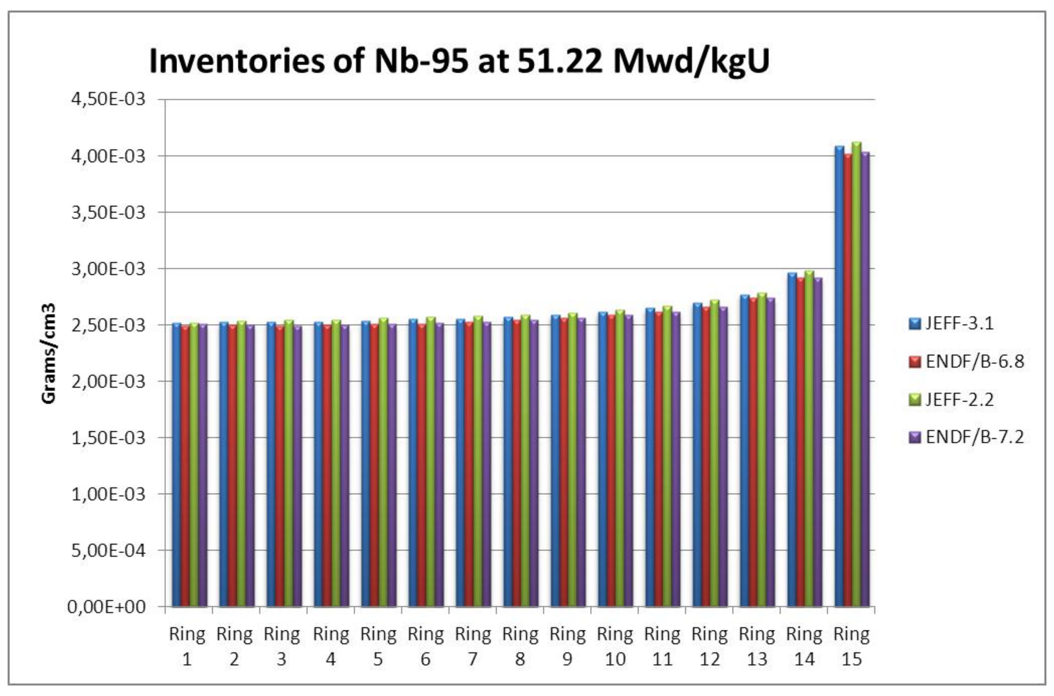
Introduction

For safety analysis knowing and understanding the source term for radioactive nuclides is important, and while different disciplines do address nuclear fuel in various forms and scale, the approaches are by necessity often very different.

Radionuclides are born in fission of heavy isotopes, and these reactions are studied by reactor physics. The behaviour of the nuclides during irradiation is covered by the field of fuel behaviour, and the release by severe accident analysis. In order to better determine the source term from spent fuel, RASTA attempted to track these nuclides from birth, through fuel rod reactor life to release during the accident.

			Diffusion in matrix				Inventory includes		
	Half-life	Grain release model	Diffusion rate based on	Diffusion rate I/Xe	Diffusion rate Cs/Xe	Grain boundary release	Gap	Grain boundary	HBS
ANS/ ANSI-5.4	Short	Model developed from Booth	Noble gases	Precursor effect	Precursor effect	Experimental interlinkage threshold	Yes	No	No
	Long	Correlated to FGR	Noble gases	1	2	As per FGR	Yes	No	No
Repository	Long	Correlated to FGR	Noble gases	1	1/3	GB included in IRF	Yes	Yes	Varies
MELCOR	N/A	Arrhenius equation (evaporation)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ASTEC	N/A	Model developed from Booth	Iodine	1	2	Instant release limited by evaporation rate	Yes	Yes	No

Assumptions on nuclide behaviour differ depending on used methodology.

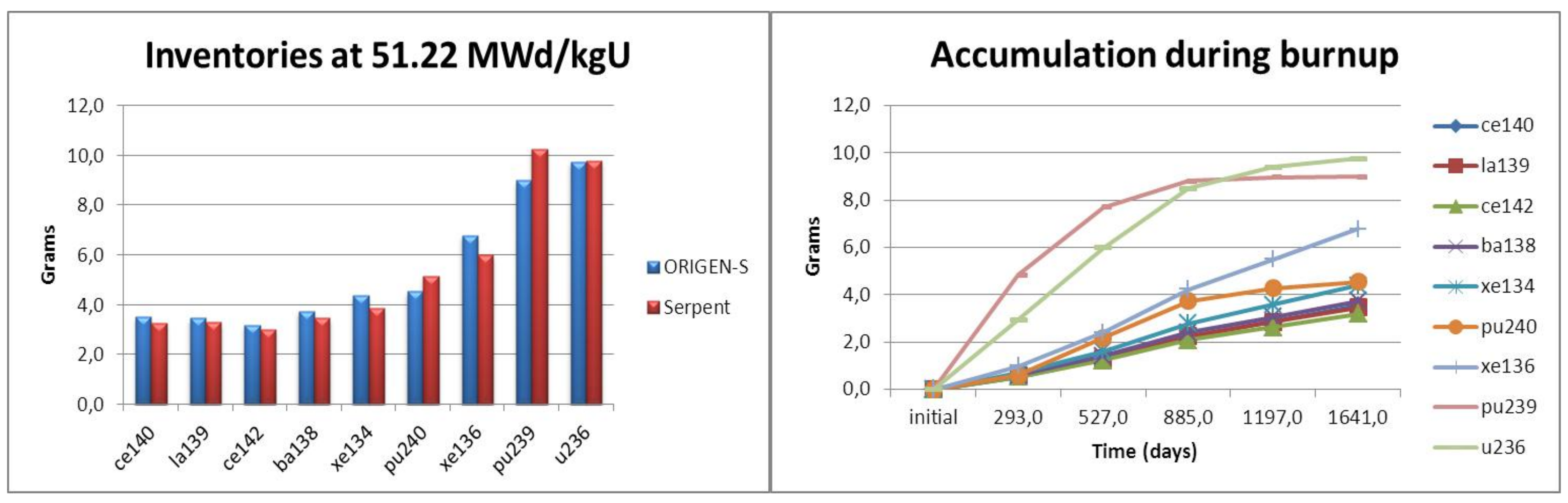


Inventory from pellet centre to the rim region. Also effect of different libraries is shown.

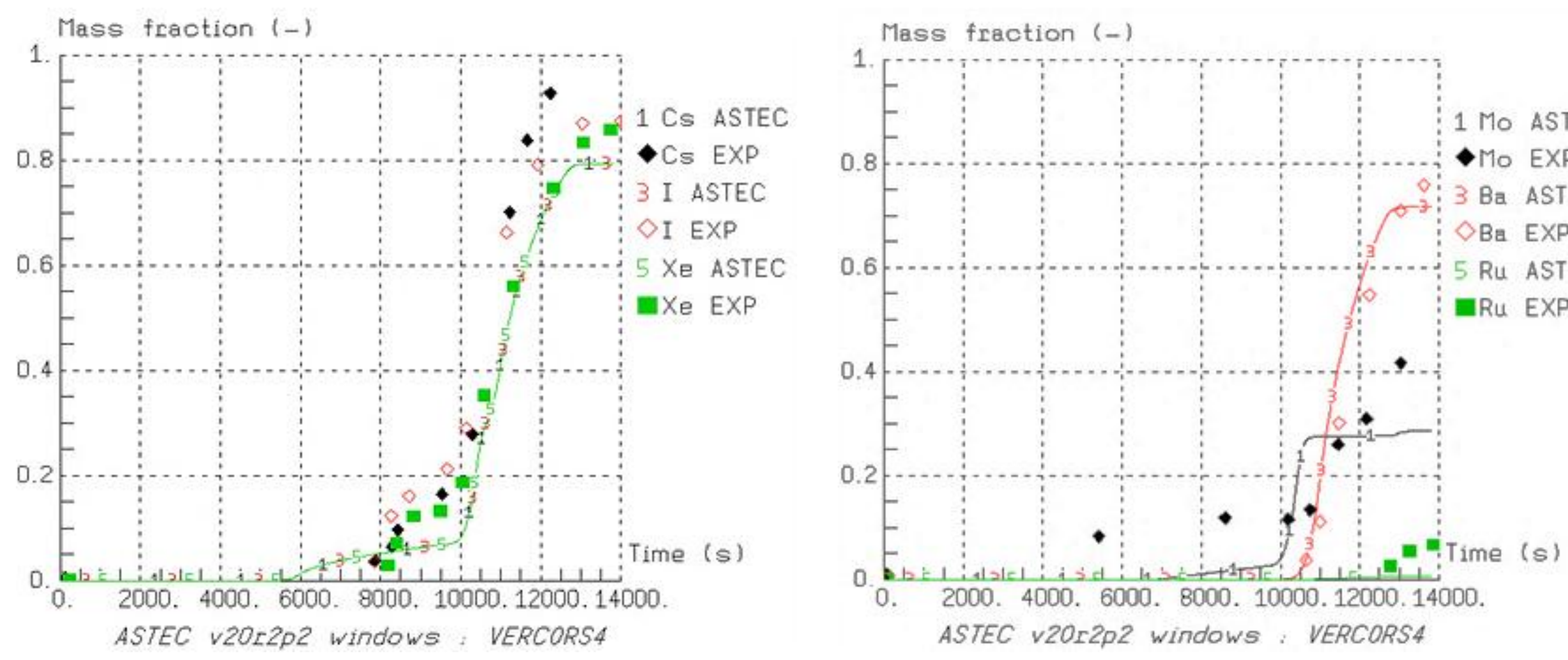
Reactor physics

Reactor physics investigations in RASTA included

- Calculation of activity inventories for a PWR rod for a burn-up of 51.22 MWd/kgU with point-depletion code ORIGEN-S.
- Investigation of cooling (decay) period of 10 000 years.
- Calculation of same case with Monte Carlo code Serpent including fuel rod geometry model.
- Effect of different cross section libraries was studied with Serpent.



Nuclide inventories calculated depend on both the codes used and the irradiation history.



Release fraction of radionuclides depend on their volatility. Volatile nuclides (left) are released much more readily than the semi-volatile ones (right). Figures are from ASTEC simulation of VERCORS experiment.

Severe accident analysis

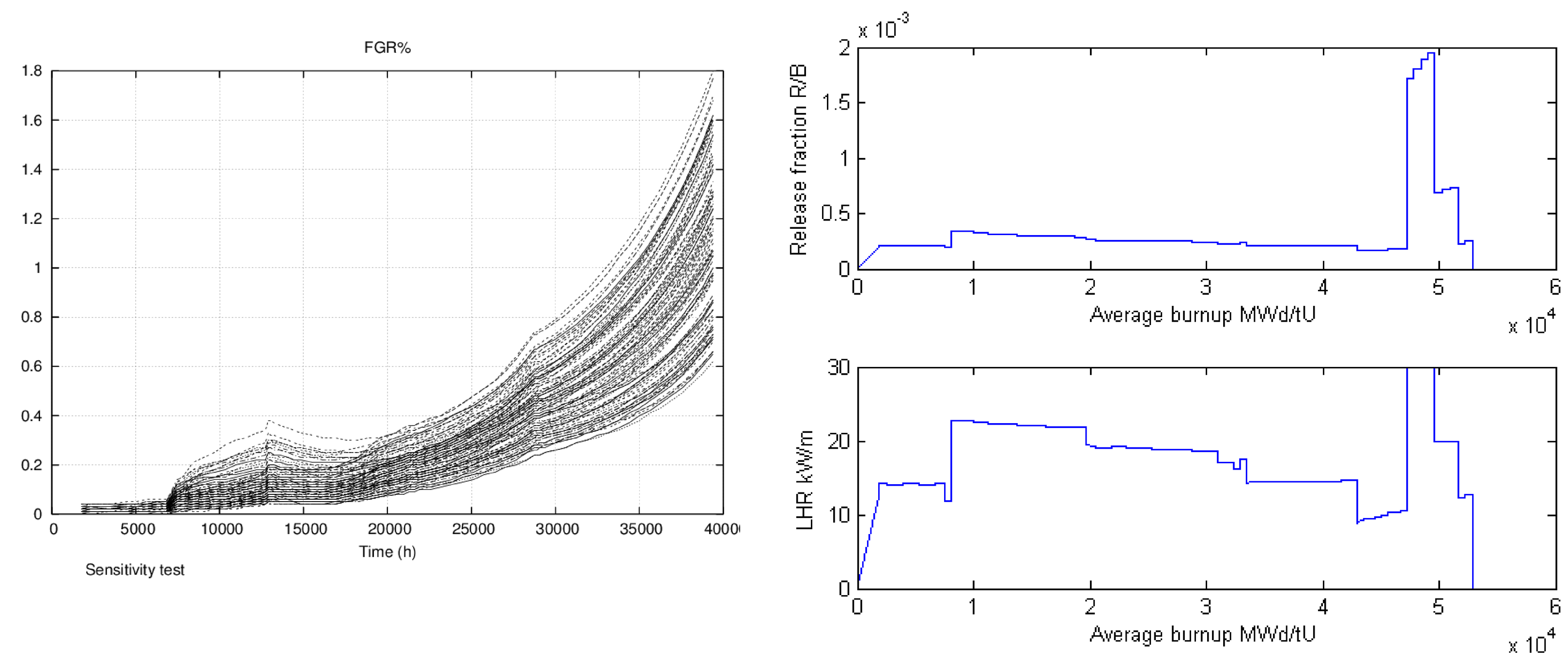
Severe Accident analysis in RASTA included

- State of the art review of the severe accident analysis regarding radionuclide release.
- Details of radioactive nuclides and their behaviour in case of severe accident.
- Code runs with ASTEC, with an attempt to simulate also the effect of the high burnup structure.

Fuel behaviour

Fuel behaviour analysis in RASTA included

- Amount of readily released nuclides during accident or in repository were studied by literature survey.
- ANSI/ANS-5.4 recommended models were implemented into VTT's fuel behaviour code ENIGMA.
- The limitations of the models were discussed.
- The effect of high burnup structure was investigated. HBS is not taken into account by the models that are based solely on conventional fission gas release models.
- Effect of environment to the actual release was briefly discussed.



Release fraction of long-lived fission products depend on power history (left, also statistical variation shown), whereas for short-lived nuclides the governing factor is the current power (right).

While the combining of the different fields as they currently are is challenging, there are some possibilities to synergy. Using reactor physics tools capable of spatial discretization is necessary for determining the HBS inventory. Fuel performance studies can provide insight how the HBS should be modelled in severe accident codes, however the end effect is probably very small considering the energetic nature of the postulated accidents in these scenarios. Nuclide release in severe accidents is affected by fuel oxidation, which is not taken into account by ANSI/ANS-5.4 but could be important in some cases, and taking note of these severe accident models could benefit the development of fuel performance codes. There is also discrepancy between the assumptions made on the diffusion rate of various nuclides between the accident analysis literature and final repository literature, which is noted in the report but left unresolved.

RASTA is reported in VTT Research Report VTT-R-00647-13.