

IRSN

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PROGRESS IN MODELLING FISSION-PRODUCT RELEASE: AN UPDATE WITH RESPECT TO IRSN'S RELEASE CODES

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Outline

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2. Improvement of ASTEC/ELSA

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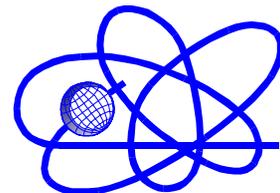
4. Conclusions



Chooz B (EDF)

Context

- Two codes developed, different objectives...
- ELSA, part of integral ASTEC code, semi-empirical tool for reliable and rapid calculation of release of all FPs, actinides and structural materials from degrading cores for all LWR SA core configurations
- MFPR, developed with the Nuclear Safety Institute of the Russian Academy of Science, highly-mechanistic approach modelling grain-scale and sub-grain phenomena for insight into state of fuel and FPs for all transients, SA or otherwise
- Both codes presented in some detail 2 years ago



IBRAE

Improvement of ASTEC/ELSA

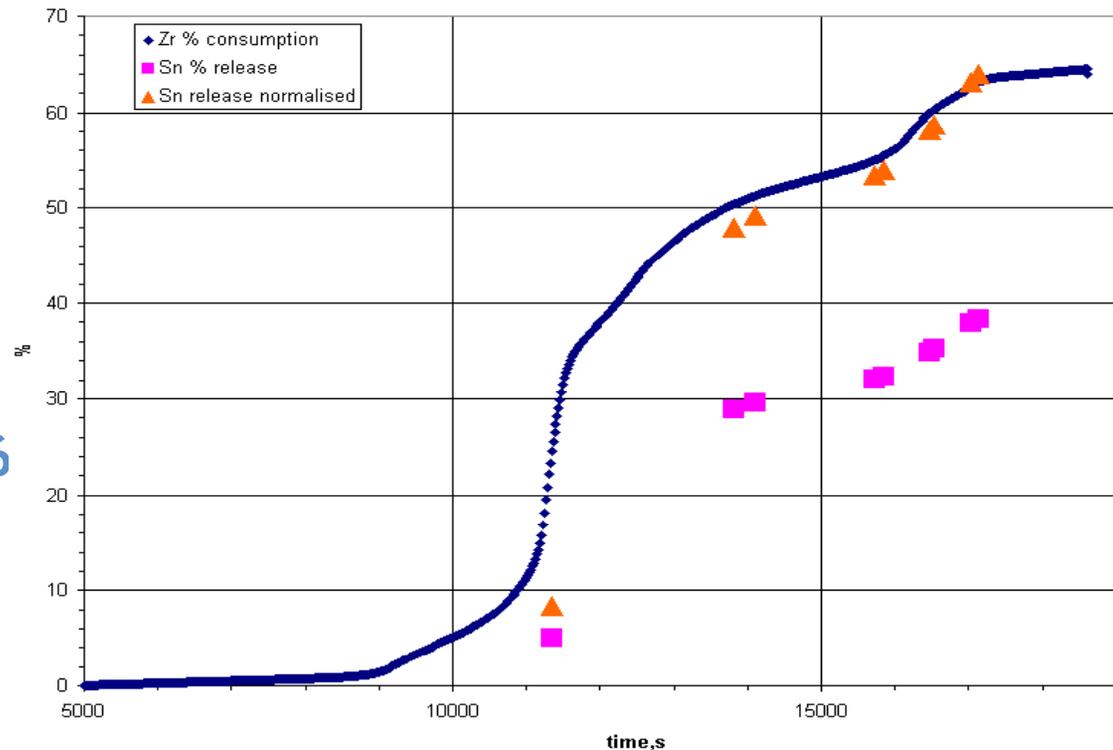
- Validation studies (e.g., ISP-46) showed deficiencies in two key areas
 - Release of so-called semi-volatile FPs, Ba, Mo, Ru, etc.
 - significant improvement required:
can contribute substantially to the source term;
major role in core degradation via decay heating
 - Release of structural elements
 - improvement for Ag-In-Cd control rods:
impact on downstream chemistry, esp. iodine
 - addition of other alloys, Cr, Fe, Nb, Ni, Sn (urgent), Zr:
impact on downstream chemistry + high aerosol source

Improvement of ASTEC/ELSA

- Release of semi-volatile FPs where chemistry determines evaporation from UO_{2+x} or precipitate phase
 - Speciation of 8 FPs reassessed using mainly GEMINI 2 (Thermodata-IRSN) + FACT-web, MFPR database, report AECL-9552
 - Total pressure
$$P_M = \gamma_{\text{MO}_q} \cdot x_{\text{MO}_q} \cdot \sum_1^n P_{\text{MO}_x\text{Hy}}$$
 - γ_{MO_q} activity coeff.
 - x_{MO_q} mole fraction in solid solution (Raoult)
 - $P_{\text{MO}_x\text{Hy}}$ species vapour pressure
 - Evaporating species: Sr, La, Ce, Eu as M + MO;
Ba as Ba + BaO + empirical treatment;
Ru as Ru + 4 oxides, separate phase;
Mo as Cs_2MoO_4 + empirical treatment;
Y re-classed as non-volatile

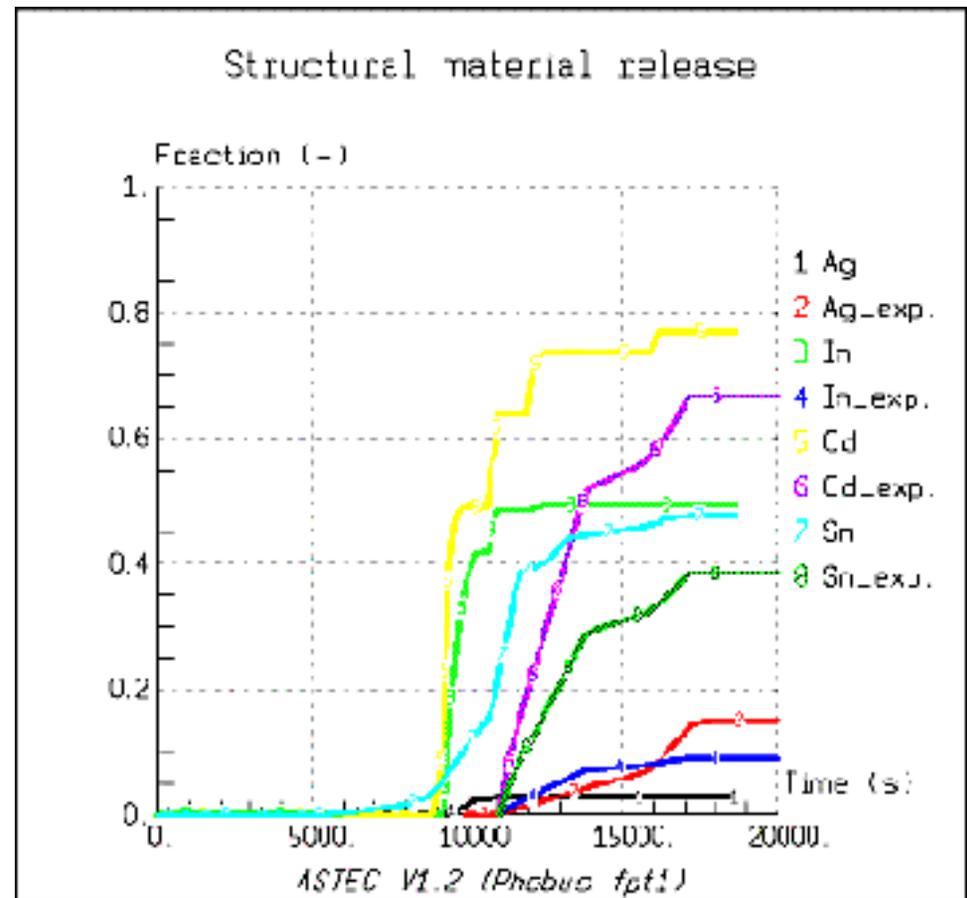
Improvement of ASTEC/ELSA

- Release of structural elements
 - Require chromium, iron, niobium, nickel, tin and zirconium, tin highest priority
 - Correlation between Zrly oxidation and Sn release, e.g., Phébus FPT1, linearly proportional with factor 0.6
 - Requires confirmation in reducing conditions



Improvement of ASTEC/ELSA

- Release of structural elements
 - Ag-In-Cd improvement: mass transfer at surface dealt with as for molten pool of corium; progression fixed by Fe_3O_4 melting (canister partially oxidized)
 - In overestimated: chemistry (In , In_2O , InOH , In_2O_3)?
 - Pursued in SARNET

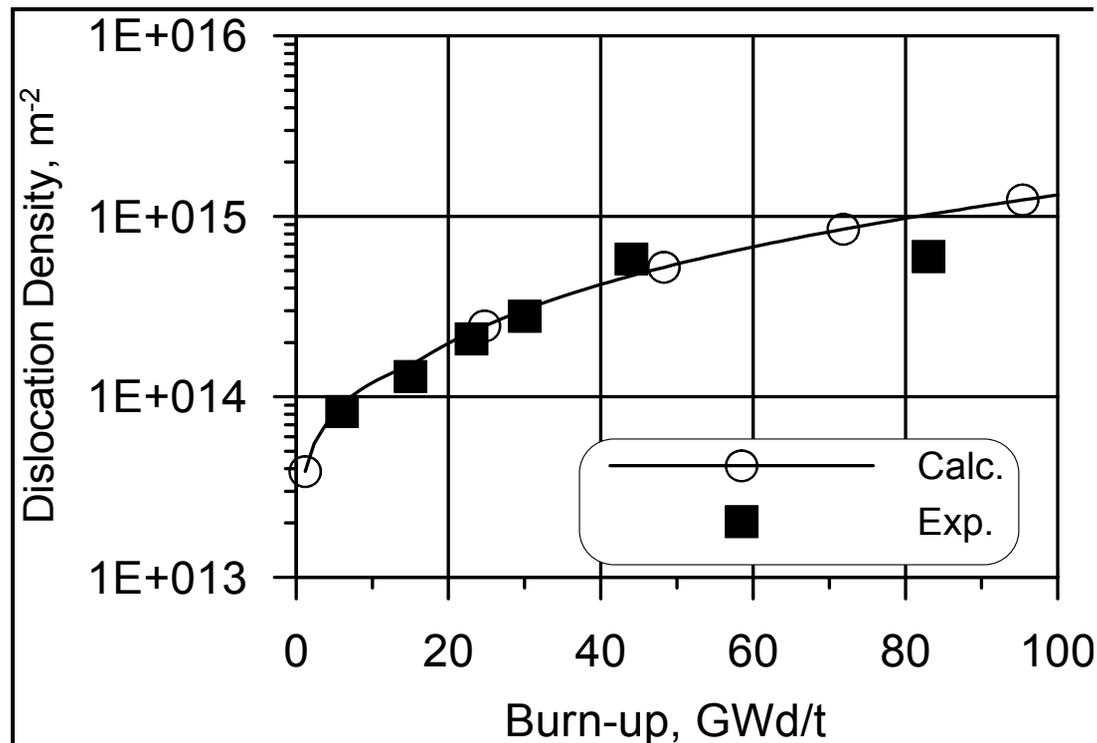


Improvement of MFPR

- Evolution of the code to treat more than just SAs
 - Both SA and especially design-basis LOCAs affected by pre-transient state of fuel, i.e., evolution during irradiation regime
 - Improvements relate mainly to fission gases & modelling of irradiation-regime phenomena for higher burn-ups
 - point-defect evolution (vacancies, interstitials, fission atoms)
 - extended-defect evolution (bubbles, pores, dislocations)
 - fuel densification
 - improved model for grain growth
 - Illustration: dislocation density increases with burn-up suppressing generation of intra-granular-bubbles → stabilization of intra-granular-bubble concentration + increase in mean size + pinning of dislocations

Improvement of MFPR

- Evolution of the code to treat more than just SAs
 - Dislocation density: comparison with data from Kashibe et al. (1993)



Improvement of MFPR

- Evolution of the code to treat more than just SAs
 - o Post-irradiation intra/intergranular gas distribution

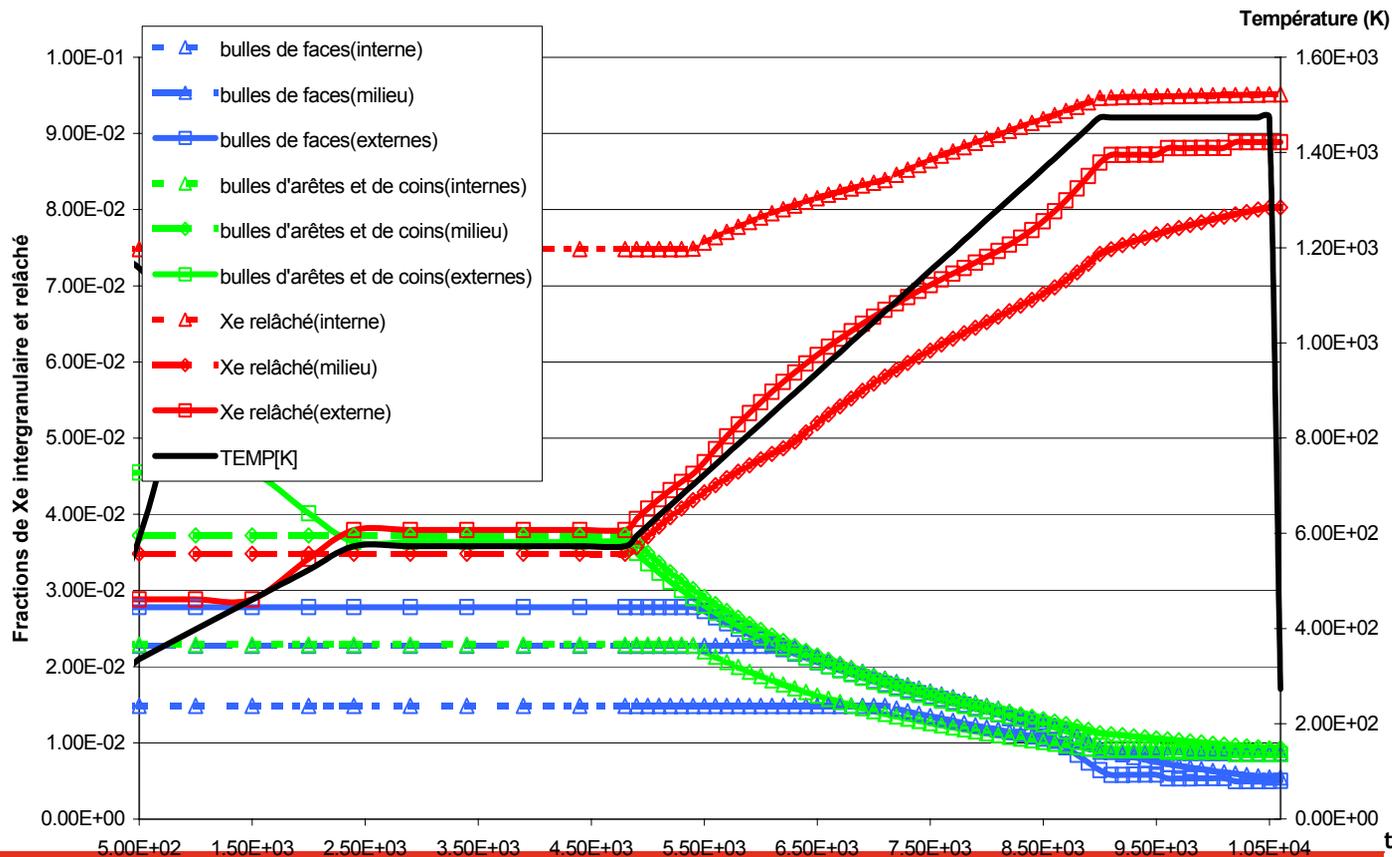
r (mm)	Gaz intra		Gaz inter		Rétention	
	exp	MFPR	exp	MFPR	exp	MFPR
0.9	73	83.8	14	6.8	87	90.6
1.3	73	84.2 <i>(79.9)</i>	14	7.0 <i>(6.72)</i>	87	91.2 <i>(86.6)</i>
2.0	73	84.6	14	7.6	87	92.2
2.4	87	84.7	8	8.2	95	92.9
3.0	87	84.6 <i>(79.3)</i>	8	9.0 <i>(8.96)</i>	95	93.6 <i>(88.4)</i>
3.7	88	83.8	8	9.5	96	93.3

Data from ADAGIO test 1065, burn-up of 60GWd/tU;

Thermal & fission conditions from TOSUREP

Improvement of MFPR

- Evolution of the code to treat more than just SAs
 - DB LOCA: comparison with data from GASPARD test A₀, burn-up of 60GWd/tU



of
60GWd/tU

Measured
Xe release:

5.9% during
irradiation;

15.3% during
transient

Conclusions

- Two codes are developed with different objectives
 - ASTEC/ELSA: semi-empirical for reliable and rapid calculation of release of all FPs, actinides and structural materials from degrading cores, all core configurations
 - MFPR: highly-mechanistic for insight into the state of the fuel and FPs for all types of transient, SA or otherwise
- Priorities for improvement were identified and have been partly accomplished

Conclusions

- Next steps

ELSA: improve coverage of all releases

- Structural: must still add release of chromium, iron, niobium, nickel and zirconium
- Further improvement of Ag-In-Cd: necessary w.r.t. In.

MFPR: more reliable tool for analysing diverse situations (irradiation regime, transients, DB LOCA, SA)

- Fission gases: improvement of dislocation model, intergranular behaviour, key parameters...
- Chemically-active elements: thermodynamic data, diffusion coefficients, conditions of formation and behaviour of separate phases
- Extend modelling to MOX fuel and special features (e.g., rim)
- Implement code in a more global tool by coupling to a fuel code (esp. mechanical phenomena including the cladding)

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