D7.1 – Report describing the irradiation experiments selected for the assessment of fuel performance codes

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SUMMARY

This deliverable presents the first results of the task 7.2 of the INSPYRE project, whose objective is to assess the improved versions of fuel performance codes after the implementation of the new models and properties obtained in the project by comparison against the results of irradiation experiments.

It synthesises first the assessment strategy of the fuel performance codes used in the project; then the criteria used for the selection of the experiments and specific pins used for the benchmark planned.

The basic information on the irradiation experiments chosen, SUPERFACT, RAPSODIE-I and NESTOR-3, are then presented. The detailed information on the irradiation experiments selected is not publicly available. It has been made available to the INSPYRE partners and is collected in an internal INSPYRE document.

CONTENT

GLOSSARY

ESNII	European Sustainable Nuclear Industrial Initiative
FIMA	Fissions per Initial Metal Atoms
INSPYRE	Investigations Supporting MOX Fuel Licensing for ESNII Prototype Reactors
MA	Minor Actinides
MOX	Mixed Oxide fuel
WP	Work Package

1 INTRODUCTION

One of the objectives of the INSPYRE project is to transfer the knowledge acquired in the project using basic and technological research to the engineering and industrial scale. This objective is in the focus of WP7 and will be achieved through the implementation in fuel performance codes of the models and material properties developed / obtained in INSPYRE. The expected outcome of this knowledge transfer is the improvement of the predictive capabilities of fuel performance codes when applied to the simulation of fast reactor conditions.

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It synthesises first the assessment strategy of the fuel performance codes used in the project; then the criteria used for the selection of the experiments and finally the experiments and specific pins used for the benchmark planned.

The basic information on the irradiation experiments chosen, SUPERFACT, RAPSODIE-I and NESTOR-3, are then presented. The detailed information on the irradiation experiments selected is not publicly available. It has been made available to the INSPYRE partners and is collected in an internal INSPYRE document [1].

2 FUEL PERFORMANCE CODES ASSESSMENT STRATEGY

Several actions are planned in INSPYRE to assess the improvement brought about by the inclusion of the new data in fuel performance codes. The assessment strategy foresees to benchmark the simulation results between several fuel performance codes developed and/or used by INSPYRE partners-: GERMINAL (CEA), TRANSURANUS (JRC-Karlsruhe), MACROS (SCK.CEN). POLIMI and ENEA participate in the task using TRANSURANUS. Two benchmarks will be performed on the simulation of:

- integral irradiation experiments (Task 7.2).
- case studies relevant for ESNII prototypes (Task 7.3).

Simulation results *prior and after* the implementation of the new models/correlations will be compared, allowing us to (1) identify the criticalities and limitations in the codes, (2) quantify the improvement in the predictive capabilities by comparison with experimental results, and (3) quantify the spread in the code predictions, providing important design information for the ESNII prototypes (represented in the INSPYRE User Group).

The present document concerns the benchmarks on the selected irradiation experiments and presents the first results of the task 7.2 of the project.

3 SELECTION CRITERIA FOR THE IRRADIATION EXPERIMENTS

Pins irradiated in the SUPERFACT, RAPSODIE-I and NESTOR-3 experiments have been selected by INSPYRE partners for the assessment of fuel performance codes predictive capabilities [2]. These experiments involve MOX fuel with a plutonium content spanning from 22.5% (NESTOR-3) to 30% (RAPSODIE-I), with SUPERFACT at 24% (with 2% of minor actinides, MA). The linear heat rate for these experiments is in the range 250 – 500 W/cm. The burnup range is 6–13 at.%. These irradiation conditions are comparable to those envisaged for several ESNII prototypes, in line with the interests of the INSPYRE end-users.

The post-irradiation examination results of the selected experiments (axial cladding profile, size of the central hole and size of the columnar grain region at different axial positions, radial profiles of fission gas and actinides concentrations, amount of fission gas and helium released) allow us to evaluate the impact of the models/properties developed in the WP6 of INSPYRE once implemented in fuel performance codes. These models/properties cover

- fission gas behaviour, which will impact the fission gas radial profiles, the volume of released gas and geometrical changes
- fuel thermal properties, which will impact the margin to melt and the fuel restructuring
- mechanical properties, which will impact the cladding profile and the central hole.

4 EXPERIMENTS SELECTED

4.1 SUPERFACT

The SUPERFACT irradiation experiment [3,4,5] was jointly conducted by the Commissariat à l'Énergie Atomique (CEA), France and the Institute for Transuranium Elements (ITU), now Joint Research Center Karlsruhe, Germany between 1984 and 1993. The goal of the experiment was to study how mixed oxide fuel (MOX) containing the minor actinides (MA) Np and Am behaves under irradiation in a fast spectrum reactor and to demonstrate the feasibility of transmutation of MA through homogenous (i.e., low content MA fuel) and heterogeneous (i.e., high MA content) fuel concepts. Within INSPYRE, we focus on the homogenous MOX concepts, represented by the fuel pins SF7, SF13 bearing 2 wt.% of ^{237}Np, and SF4, SF16 bearing 1.8 wt.% of ^{241}Am.

The irradiation of the fuel, manufactured at ITU, took place in the Phénix reactor between the 38th and 42nd cycles (October 1986 – January 1988). Post-irradiation examinations took place at CEA and ITU, covering a wide set of non-destructive and destructive analyses.

4.2 RAPSODIE-I

During the RAPSODIE-I (also named SNR 1) experiment [6,7], two fuel assemblies of 34 pins each were irradiated in 1971-1972, one with DIN 1.4988 cladding and another with DIN 1.4970 cladding, attaining a peak burnup level of about 10 % FIMA and a peak cladding damage of about 35 dpa_{NRT}. The goal of the RAPSODIE-I experiment, which adopted the specifications of the SNR-Mk-1a core design, was to confirm the good performance of the 1.4988 cladding and to extend the investigation to the 1.4970 cladding.

4.3 NESTOR-3

The NESTOR-3 experiment [8] was performed between 1984 and 1987 on a standard PHENIX fuel assembly made of 217 pins, featured by a peak burnup equal to 13.28 at.% and peak cladding damage at the end of life equal to 117.2 dpa. The data considered in INSPYRE are coming from the fuel pin number 110, except for the fission gas release, which was inferred by measurements from pin number 78. These two pins were located close to the centre of the assembly: first row for pin 110 and second row for pin 78.

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