

JRC SCIENTIFIC AND POLICY REPORTS

DELIVERABLE (D-N^o: 2.1) Status of fission gas release studies (24 months)

FIRST-Nuclides
(Contract Number: FP7-295722)

D.H. Wegen, E. González-Robles, A. Puranen

2013



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Classification: No restriction
Unit: E05 and E02
Action No:51102

European Commission
Joint Research Centre
Institute for Transuranium Elements

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JRC 87028

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Printed in Germany





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Author(s): D.H. Wegen, E. González-Robles, A. Puranen

Reporting period: e.g. 02/01/13 – 31/12/13

Date of issue of this report: 31/12/13

Start date of project: 02/01/12

Duration: 36 Months

Project co-funded by the European Commission under the Seventh Euratom Framework Programme for Nuclear Research & Training Activities (2007-2011)

Dissemination Level

PU	Public	X
RE	Restricted to a group specified by the partners of the FIRST-Nuclides project	
CO	Confidential, only for partners of the FIRST-Nuclides project	



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Status of fission gas release studies (24 months)

D.H. Wegen, E. González-Robles, A. Puranen

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Objectives

In the first component of work package 2 (WP2) “Experimental determination of fission gas release” the focus is on the quantification of fission gases and fission gas release in high burn-up (HBU) UO_2 spent nuclear fuels (SNF). Fission gas sampled in the plenum of a fuel rod are analysed as well as the grain boundary inventory and the cross sectional distribution of fission gases and volatile fission products. The experimental part in WP2 started in project month 4 and will end in project month 33 [1], [3], [7].

The JOINT RESEARCH CENTRE – INSTITUTE FOR TRANSURANIUM ELEMENTS (JRC-ITU) is the leading organization of WP2. In the first project year the fission gas release (FGR) from a spent fuel rod owned by KIT was measured [1], [2]. The determination of the inventory of fission gas and fission products in grain boundaries are foreseen for the third project year.

The KARLSRUHER INSTITUT FÜR TECHNOLOGIE (KIT) analysed in the first project year fission and activation products in the fission gas sampled at JRC-ITU from the plenum of a fuel rod segment by puncturing. The development, testing and implementation of analytical methods for fission and activation products have started in the first project year one and were continued in the second. Leaching experiments in which gas and solution analyses are foreseen were started in the first year and last until project month 33 [1].

STUDSVIK NUCLEAR AB (STUDSVIK) investigates in the frame of WP2, the radial fission gas and volatile fission product distribution (Xe, I, and Cs) by Laser-Ablation Mass Spectroscopy (LA-MS) on HBU boiling water reactor (BWR) SNF [1].

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Status and results

In the second year of the experimental work programme in WP2 first results have been obtained by KIT and Studsvik while JRC-ITU has foreseen to determine the inventory of fission gas and fission products in grain boundaries by Knudsen cell effusion tests in the coming project year.

KIT has analysed the experimental FGR data obtained after the plenum puncturing of the PWR fuel segment N0204 and determined the fission gas release from the experimental results and the theoretical inventory for Xe and Kr calculated with the ORIGEN code. The fission gas release was 8.35% of the total inventory [4], [5].

KIT started the leaching experiment under anoxic conditions. A cladded segment pellet was introduced in an autoclave together with 220 ml of bicarbonate water (19 mM NaHCO₃ + 1 mM NaCl). Then the autoclave was pressurised with Ar/H₂ (p_T = 40 bar; p_{H₂} = 3 bar). First gas samples have been analysed. After a cumulative contact time of 57 days, 4.3% of the Xe and 17% of the Kr inventories were released into the gas phase [4], [5], [8], [9], [10].

STUDSVIK evaluated the Laser Ablation data obtained in 2012 on cross sections from a standard UO₂ fuel and an Al/Cr-additive fuel. The findings of the Laser Ablation study on both pellets indicate cesium and iodine profiles that are very similar and appear to follow the radial burnup profile (as indicated by ¹⁴⁰Ce). Cesium, iodine and to some extent selenium also appear to collect in some fuel cracks. Selenium was tentatively identified by the good agreement of the isotopic ratios of mass 77, 79 and 82 with the calculated inventory. For the additive pellet chromium and especially aluminum are heterogeneously distributed in the pellet. Further analysis of the data is underway [6], [11], [12].

Dissemination

Publications, reports, or contributions in reports, proceedings:

- [1] Wegen, D.H., González-Robles, E., Puranen, A. (2012). *DELIVERABLE (D-N°: 2.1) - Status of fission gas release studies (12 months), FIRST Nuclides (Contract Number: FP7-295722)*. JRC Scientific and Policy Reports, JRC76116, European Atomic Energy Community, Germany.
- [2] Wegen, D.H., Papaioannou, D., De Weerd, W., Rondinella, V.V., Glatz, J.-P. (2013). *Fission gas release measurement on one 50.4 GWD/t_{HM} PWR fuel segment*. 1st Annual Workshop Proceedings, 7th EC FP – FIRST-Nuclides, 9th – 11th October 2012, Budapest, Hungary. KIT SCIENTIFIC REPORTS 7639, pp 201.
- [3] Wegen, D.H. (2013). *Overview WP2: Gas Release + RIM and Grain Boundary Diffusion*. Proceedings of the 2nd Annual Workshop of the FIRST- Nuclides Project, November 5th-7th, Antwerp, Belgium.
- [4] González-Robles, E., Bohnert, E., Loida, A., Müller, N., Metz, V., Kienzler, B. (2013). *Fission gas measurements and description of leaching experiments with of KIT's irradiated PWR fuel rod segment (50.4 GWD/t_{HM})*. 1st Annual Workshop Proceedings of the

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Collaborative Project “Fast /Instant Release of Safety Relevant Radionuclides from Spent Nuclear Fuel” (7th EC FP CPFIRST-Nuclides), 9-11 October 2012, Budapest (Hungary), KIT SCIENTIFIC REPORTS 7639, pp 231.

- [5] González-Robles, E., Bohnert, E., Müller, N, Herm, M., Metz, V. (2013). *Determination of the fission gas release in the segment N0204 and gas phase result of anoxic leaching experiment*. Proceedings of the 2nd Annual Workshop of the FIRST- Nuclides Project, November 5th-7th, Antwerp, Belgium.
- [6] Roth, O., Puranen, A., Low, J., Granfors, M, Cui, D., Askeljung, C. (2013). *Spent fuel leaching experiments and laser ablation studies performed in Studsvik - Status and preliminary results*. Proceedings of the 2nd Annual Workshop of the FIRST- Nuclides Project, November 5th-7th, Antwerp, Belgium.

Poster and presentations:

- [7] Wegen, D.H. (2013). *WP2: Gas Release & Rim and Grain Boundary Diffusion*. 2nd Annual Workshop, 7th EC FP – FIRST-Nuclides, 5th-7th November, Antwerp, Belgium.
- [8] González-Robles, E., Wegen, D.H., Papaioannou, D., Kienzler, B., Nasyrow, R., Metz, V. (2013). *Physical characterisation of spent nuclear fuel: First steps to further Instant Release Fractions investigations*. 8th EC Conference on the Management of Radioactive Waste, EURADWASTE 2013, October 14th-17th, Vilnius, Lithuania.
- [9] González-Robles, E., Bohnert, E., Metz, V., Wegen, D.H., Papaioannou, D., Kienzler, B. (2013). *Physical characterisation and calculation of the initial and boundary conditions of a commercial UO₂ spent nuclear fuel regarding the radionuclide release*. 37th Symposium on the Scientific Basis for Nuclear Waste Management, September 29th–October 3rd, Barcelona, Spain.
- [10] González-Robles, E., Bohnert, E., Müller, N, Herm, M., Metz, V. (2013). *Determination of the fission gas release in the segment N0204 and gas phase result of anoxic leaching experiment*. 2nd Annual Workshop of the FIRST- Nuclides Project, November 5th-7th, Antwerp, Belgium.
- [11] Puranen, A., Roth, O., Granfors, M. (2013). *Investigating the radial distribution of potential rapid release radionuclides in irradiated nuclear fuel*. Symposium: E No. 2 15, E-MRS 2013 Spring Meeting, May 27-31, Strasbourg, France.
- [12] Puranen, A., Granfors, M, Roth, O. (2013). *Laser ablation experiments at Studsvik*. 2nd Annual Workshop of the FIRST- Nuclides Project, November 5th-7th, Antwerp, Belgium.

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Abstract: This report summarises the activities planned and performed in project months 13 - 24 by the beneficiaries collaborating in the component “*Experimental determination of fission gas release*” of work package 2 (WP2) of the CP – FIRST-Nuclides project in 2013. The main achievements in the second project year are given.

The research leading to these results has received funding from the European Union’s European Atomic Energy Community’s (EURATOM) Seventh Framework Programme FP7/2007-2011 under grant agreement no. 295722 (FIRST-Nuclides project).

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