

THOMOX

Technical Proposal

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1 Introduction

SCK•CEN has a long standing history with MOX fuel, both for Light Water Reactor (LWR) and Fast Reactor (FR) fuels. The first 12 MOX fuel pin loading in a Pressurised Water Reactor (PWR) was performed in 1963 in SCK•CEN's demonstration PWR, the BR3. Since then, SCK•CEN together with its daughter company, BELGONUCLEAIRE, continued the research and development of MOX fuel both for LWR and FR applications. Many research projects were jointly conducted to improve the understanding of MOX fuel behaviour up to ultra high burnup and to obtain licensing data for PWR and BWR applications.

Independently from BELGONUCLEAIRE, SCK•CEN also conducted more fundamental oriented research, together with other research institutes. In the framework of European Union co-sponsored research projects, SCK•CEN managed several fuel irradiation projects on innovative MOX fuels (OMICO, MIMAS-PV and LWR-DEPUTY). In the framework of these projects, fuels and fuel pins were designed, manufactured and irradiated to a relatively low burnup (10-15 GWd/tHM) under representative PWR conditions.

Some of these fuel rods are now selected for further irradiation, with the intention to reach a burnup of ~30-40 GWd/tHM. The present document briefly summarises some key data of the fuel pins that are selected for further irradiation in the CALLISTO loop of the BR2 reactor.

2 General information

In the EU-sponsored 5th Framework Project OMICO (standing for "Oxide Fuels – Microstructure and Composition Variations"), the behaviour of three different fuel compositions (UO_2 , $(U,Pu)O_2$ and $(Th,Pu)O_2$) has been studied. For each composition, two different microstructures were inter-compared (homogeneous and fine dispersed ceramic-in-ceramic (CERCER)). Two sets of six fuel rods were produced, one set of instrumented fuel pins, and a second set of non-instrumented fuel pins. The fuel pins were assembled in an experimental assembly and irradiated under representative PWR conditions in the pressurized water loop of the BR2 materials test reactor. The fuel rods were loaded in a dedicated in-pile basket. The results of the OMICO program are published in [1].

In a bilateral context, SCK•CEN together with the Institute for Transuranium Elements (ITU) developed the MIMAS-PV project (standing for "MIMAS-Process Variation"), in which advanced MIMAS-MOX fuels were developed and irradiated. The fuels developed in the MIMAS-PV project, are $(U,Pu)O_2$ fuels produced according to the MIMAS production route, with either the use of additives or using a modified diluting matrix with more reactive UO_2 powder to improve the (U,Pu) homogenisation during sintering. These fuel rods were also loaded in a dedicated in-pile basket.

In the EU-sponsored 6th Framework Project LWR-DEPUTY (standing for "Light Water Reactor fuels for Deep Burning of Pu in Thermal Systems") [2], PuO_2 containing ceramic-in-metal (CERMET) fuels, where PuO_2 kernels are embedded in a metallic matrix (two fuel types use a FeCr alloy as matrix material, one fuel type use a matrix with natural Mo and one fuel type uses depleted Mo as matrix material), were designed, developed and irradiated. Short fuel rod segments were assembled into a rod of 1 meter length and these assembled rods were loaded in the standard assembly of the CALLISTO loop. The project is on-going and the final report of the LWR-DEPUTY project is expected by 2011.

In order to accelerate the burnup accumulation, the OMICO, MIMAS-PV and LWR-DEPUTY fuels deviate from standard LWR fuels in the sense that the pellet radius is smaller by a factor $\sqrt{2}$ and the enrichment is higher by a factor 2. Of course, the pin lengths are much smaller than those of power reactors. Otherwise, the design parameters remain similar to those of LWR fuel designs: high density sintered fuel pellets, loaded in Zr-y tubes, pressurized with He gas (Figure 1).

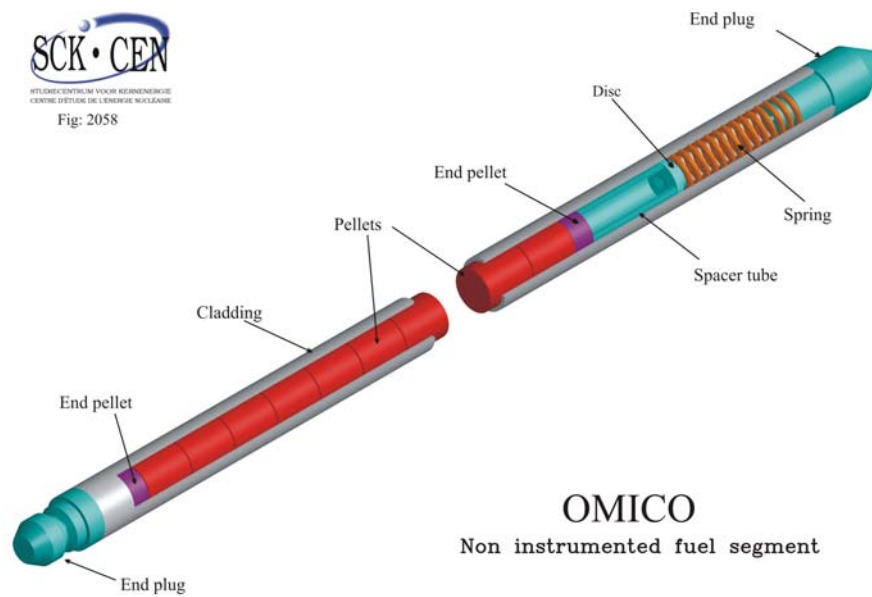


Figure 1. Schematic drawing of the non-instrumented fuel rods in the OMICO program. Identical design was used for the MIMAS-PV fuels and almost identical design was applied for the LWR-DEPUTY fuel rods.

3 Specification of segments and compound rod

Table 1. Fuel fabrication data.

		H	D	F
Original project		OMICO	MIMAS-PV	MIMAS-PV
Fuel type		(Th,Pu)O ₂	(U,Pu)O ₂	(U,Pu)O ₂
Powder technology		SOLMAS	MIMAS using active UO ₂	MIMAS using Al ₂ O ₃ -SiO ₂ additives
Enrichment	Pu/(total HM)	12.8%	8.9%	8.9%
Density	(%TD)	96.6%	95.2%	95.0%
Pellet diameter	mm	5.9	5.9	5.9

Table 2. Pu vector used for the fabrication of the fuels.

²³⁸ Pu	0.012%
²³⁹ Pu	91.500%
²⁴⁰ Pu	8.304%
²⁴¹ Pu	0.140%
²⁴² Pu	0.044%
²⁴¹ Am (relative to total Pu)	0.695%

Table 3. Fuel pin data and achieved rod average burnup.

	H	D	F
Achieved burnup (GWd/tHM)	12.4	13.0	12.3
Cladding type	--	Zry-4	--
Outer diameter	--	7.08 mm	--
Inner diameter	--	6.07 mm	--
Fill gas type	--	He	--
Fuel pin length	--	220 mm	--
Fuel stack length	--	143 mm	--
Fill gas pressure	--	5 bar	--

3.1 Irradiation history

The OMICO and MIMAS-PV experiment was loaded during seven cycles in IPS1 of the pressurised water loop, CALLISTO. In Figure 2, the overview of the reactor operation (BR2 total power) and the average power of one of the non-instrumented rods are given. It is obvious from this figure that the reactor power is only partly correlated with the power of an individual rod. While the OMICO and MIMAS-PV experiments remained in the same position in the reactor, the rearrangement of the BR-2 driver fuel elements allows one to increase or decrease the neutron flux locally. For cycle 2004/5, one driver fuel element was loaded in a channel (F46) adjacent to IPS1 where the OMICO and MIMAS-PV experiments were loaded. For cycles 2005/1, 2005/2, 2005/3, 2005/4 and 2006/3, no driver fuel elements were loaded in the channels adjacent to IPS1. During the last cycle (2006/4), driver fuel elements were inserted in two channels adjacent to IPS1 (channels G60 and F46).

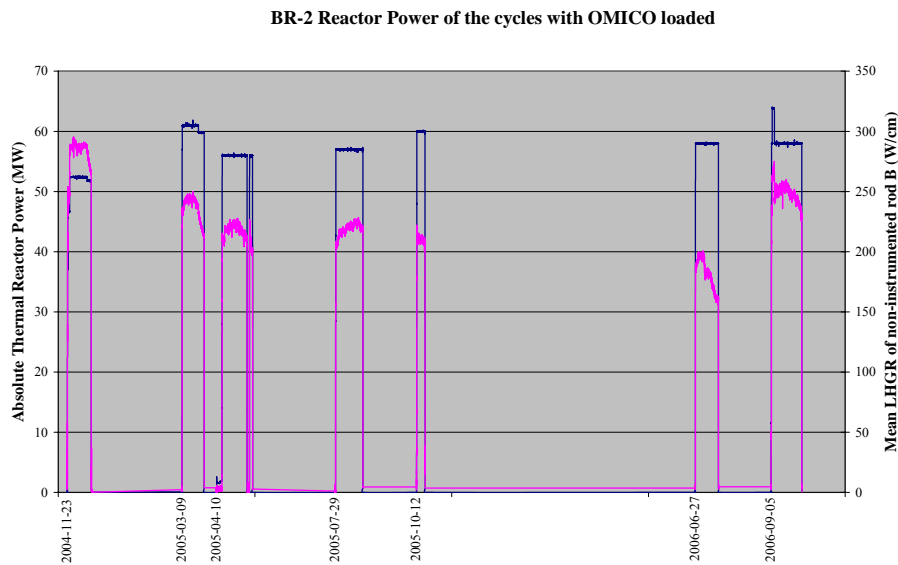


Figure 2. Reactor power (left axis, MWth, blue line) and LHGR of non-instrumented rod B (right axis, W/cm, pink line). Note the variation within each cycle for the LHGR of an individual rod due to control rod movement.

4 Project Proposal

The fuel rods of the OMICO, MIMAS-PV and LWR-DEPUTY programs were irradiated for a period of 100 to 140 days. With the applied design, a burnup of 11-14 GWd/tHM (rod average) was reached.

The presently proposed project THOMOX intends to further irradiate selected fuel rods from MIMAS-PV and OMICO experiments and conduct PIE and radiochemical analyses at medium burnup (~40 GWd/tHM). To this purpose, the end plugs of the fuel rods will be modified identical to the LWR-DEPUTY fuel segment design and three fuel rod segments will be assembled into a rod of 1 meter length such that it can be inserted in the standard CALLISTO rig.

References

1. Verwerft, M., Lemehov, S. E., Wéber, M., Vermeeren, L., Kuzminov, V., Sobolev, V., Parthoens, Y., Vos, B., Van den Berghe, S., Segura, H., Blanpain, P., Somers, J., Toury, G., McGinley, J., Schubert, A., Van Uffelen, P. & Haas, D., *Oxide Fuels: Microstructure and Composition Variations (OMICO), Final report*, EUR 23104, (Mol, 2007).
2. Verwerft, M., *LWR-DEPUTY Project Presentation*, <http://www.sckcen.be/LWRDEPUTY/>, (Mol, 2007).

5 Annexes

Design drawing